



The State of the Greenhouse Gas Emissions Reporting in European Real Estate Sector.

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Abstract

Greenhouse Gas (GHG) emissions and the associated climate change is one of the most pressing issues of our time. Real estate sector is responsible for approximately 36% of the total GHG emissions worldwide. While being the most polluting single industry, real estate also offers easy reductions in GHG emissions. This has prompted the development of various legislations and voluntary initiatives to reduce GHG emissions from real estate sector. Many of the companies in the sector choose to report their GHG emissions following some framework such as GRI G4 or EPRA guidelines.

This thesis looks at the current GHG emissions reporting in the European real estate sector. Specifically, what emissions are included in the sustainability reports. The LCA is evaluated as a future tool for integrated emissions reporting. Finally, the currently reported emissions are compared against benchmark of emissions from full LCA.

From 116 listed European real estate companies only 50 had dedicated sustainability report and only 9 acknowledged emissions arising from other than building use phase. At the same time green building certificates such as BREEAM and LEED have gained a significant popularity. Many of the companies also included in their sustainability report the number of certified buildings. Many of these certificates include Life-Cycle Assessment (LCA) which quantifies emissions throughout all stages of the buildings life-cycle including the embodied emissions in the construction materials. However, only one of the companies analysed included these emissions in their sustainability report.

In future the importance of embodied emissions will only increase due to improved energy efficiency and use of renewable energy sources. In new buildings the share of embodied emissions can account for up to 45% of the total emissions which is also illustrated by the benchmark compiled for this research. Based on emissions reported by six large real estate companies that also develop properties, the reported emissions were between 24% and 68% of average LCA emissions from similar portfolios.

Keywords Sustainability, reporting, GHG emissions, LCA, Climate change

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Arturs Alsins

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1 Introduction

1.1 Background

Climate change describes the long-term average change in weather conditions in a certain geographic area (NASA, 2005). According to Intergovernmental Panel on Climate Change (2014a), the last three consecutive decades have each been warmer than the previous one, leaving almost no doubt in the scientific community about the occurrence of climate change. The main cause of the climate change is the anthropogenic greenhouse gas emissions since the industrial revolution. Uncontrolled, the human caused emissions will lead to catastrophic and irreversible changes to the natural environment and the society (European Environment Agency, 2008).

Climate change has been a topic of debate for the past decade, however, the scientific community has been aware of it for over a century. In 1896, a Swedish scientist Arrhenius published an article about the effects of atmospheric carbon on the land temperature. Already then it was known that the combustion of fossil fuels causes carbon dioxide emissions and, while the science was not as established, Arrhenius (1896) theorized that the anthropogenic emissions of carbon dioxide are increasing the earth's temperature.

Fast forward a century and the science seems to be certain of the theories brought up over 100 years ago. All the milestones in-between then and now are important for the science but what matters for our well-being is where the science has brought us. In December 2015, the most significant agreement was reached between nation states to curb the emissions and avoid the global warming beyond 2 degrees C in Paris during the 2015 United Nations Climate Change Conference. It went even further and strongly encourages the emissions to be lowered to a level where the global warming would remain below 1.5 degrees C. It is the first major agreement that is legally binding and of which United States and China are part of. Transparency of the emissions is an integral part of this agreement and a requirement for successful implementation of it. (Center for Climate and Energy Solutions, 2015)

The EU's overall goal is to reduce the GHG emissions by 20%, produce 20% of energy from renewable sources and improve the energy efficiency by 20% by year 2020. A framework for 2030 is already in place increasing these targets to 40%, 27% and 27% respectively. By reaching these milestones the aim is to ensure that the EU will have a low-carbon economy by 2050 with the GHG emissions reduced to 80% below the levels of 1990. (European Commission, 2016)

The built environment is responsible for some 40% of European Union's total energy consumption and 36% of its Greenhouse Gas (GHG) emissions and therefore, it is a major focus point in reducing the overall GHG emissions. (Artola et al, 2016). The emissions accounting from buildings and construction industry can be challenging due to the complex supply chain and the long life-time of buildings. The GHG emissions occur throughout all the stages of buildings lifetime starting from raw material extraction until the demolition and the construction waste disposal (Säynäjoki et al, 2017).

There are various EU directives and policies aimed at building environmental performance and energy efficiency such as the Energy Performance of Buildings Directive and Energy Efficiency Directive (European Commission, 2017a). These legislations focus only on the use phase emissions and therefore exclude large part of the overall emissions from buildings which in new buildings, that have implemented significant energy efficiency measures, can constitute 50% of total emissions. Even though buildings are responsible for nearly 40% of the total GHG emissions they are not part of the EU Emissions Trading System (ETS). The sector is in serious need of systematic and reliable information on the total life-cycle emissions from buildings. (Säynäjoki et al., 2017)

The concerns about the environmental impacts of the buildings have triggered the development of wide variety of green certification systems and labels that rate or certify buildings environmental performance based on the requirements of the system. These certification and rating systems vary in their scope significantly. Some of them focus on few attributes of the building such as energy and water consumption while others take a more holistic view of the whole life-cycle of the building. Comprehensive certification systems should be science based to provide reliable results, be transparent in its criteria and certification awarding process, be independent and objective to avoid any conflict of interest and finally be progressive and aim at improving the practices instead of rewarding existing ones. (Vierra, 2016)

Majority of green certification systems and labels are purely voluntary and there is a certain cost and benefit associated with these certification systems. Buildings that acquire certification through internationally known and comprehensive systems like LEED and BREEAM has an increased up-front cost. However, it has been well documented that these certification schemes provide economic, social and environmental benefits as well as reduce risks (Zuo, 2014). Buildings with green certificates have been shown to reduce GHG emissions comparing to non-certified buildings and therefore are more sustainable (Mazingo and Arens, 2014). The green building certificates can be used to provide evidence of corporate social responsibility (Ebert et al, 2011).

Sustainability reporting is a tool for companies to account for, disclose and take responsibility for their environmental, social and economic performance. It is a way for companies to communicate to their stakeholders about their effectiveness in managing the risks to satisfy these stakeholders. The real estate industry has seen a lot of development in the reporting guidelines in recent years, yet there is a lack of consistency between the reports that would allow for easy comparison. Similarly, as with the EU directives the CSR focuses heavily on the use phase environmental impacts and therefore neglects up to 50% of the total emissions from real estate sector. (Wensen et al, 2011)

In recent years there has been a movement of divestment from the heavy polluting industries due to the risks associated with their impact on the environment (Mooney, 2017). Considering initiatives such as EU Emissions Trading System (ETS) and other initiatives that put direct or indirect cost on carbon emissions, these heavy polluting industries are seen as a risky investment. In recent years, the EU has debated the possibility to implement a direct tax on carbon or to extend the EU ETS beyond the sectors that it covers currently (Weisbach, 2011).

In one of the most notable cases of divestment, Norway's state pension fund, the world's largest sovereign wealth fund, divested from 73 companies that it deemed too risky due to their social and environmental performance. While the oil and gas fueled pension fund did not disclose the names of the companies sold, it did indicate that these were companies in the coal and energy industry as well as companies involved in mining, cement production and heavy construction. (France-Presse, 2016)

Considering that the EU is developing a common framework for core indicators for building environmental performance that include Life Cycle Assessment (LCA), this might lay groundwork for binding directives in the future that go beyond energy efficiency of the buildings. There is a large gap between the current sustainability reporting in real estate sector and the best available knowledge in the industry. The lack of actionable information on the environmental impacts in the real estate industry has the potential of elevating risks associated with the uncertainty. (Dodd et al, 2017)

The wider adoption of LCA in voluntary building certification schemes and the prevalence of certified buildings leaves a missed opportunity in the emissions reporting in real estate industry. If an LCA has been performed on a building it means that the emissions from other than use phase are known but this is almost never reported in the annual sustainability reports as it is not part of the commonly used disclosure frameworks. By reporting more qualitative data in the sustainability reports the industry leaves a greater risk of greenwashing that would not be possible by providing hard data on sustainability performance.

1.2 Purpose Statement and Research Questions

The purpose of this study is to examine the current European Union landscape in the real estate sector in regards its environmental performance and sustainability reporting. To get a comprehensive understanding of it, a closer look needs to be taken to the wider EU policies and trends. The current practises of reporting the environmental impacts in the real estate sector are evaluated and compared to the industry standards and trends. The contribution that the sustainability reporting has towards the wider goal of reducing the greenhouse gas emissions is examined. Finally, the current GHG emission reporting is compared to data from full building LCA's to estimate the share of emissions that is not reported. Therefore, to fulfil the studies purpose, three research questions are formed:

- 1. What are the current practices of GHG reporting in real estate industry?**
- 2. What is the industry outlook towards the future of sustainable real estate?**
- 3. What share of the GHG emissions is left out from emissions reporting in European real estate?**

1.3 Research methods and Data Sources

In the literature review, the study takes a wide perspective on the landscape where the real estate sector exists. The importance of climate change and GHG emissions from the real estate sector are reviewed to understand the necessity and evolution of sustainability reporting. The European Union targets towards reduction of GHG emissions are analysed to understand what role real estate sector will have towards achieving these targets. The study identifies the current legislation affecting real estate sector in Europe as well as voluntary initiatives that aim to reduce GHG emissions. The current literature on sustainability practices is reviewed to be able to draw conclusions on their suitability in the current industry landscape. This information was gathered through EU reports and publications, legal documents, scientific journals and news articles.

The empirical part of the study was conducted using a mix of qualitative and quantitative methods. To answer the first research question of the thesis a secondary research examining sustainability reports of 116 listed European real estate companies was performed to gather quantitative data of the GHG emissions reported in these reports. Further qualitative review of these reports was performed to understand the scope of the reporting. This included reviewing if the company report on green building certificates in their portfolio and if any concrete actions towards mitigating environmental burdens are reported.

To answer the second research questions a questionnaire answers from 41 experts in the real estate industry were analysed. Google forms was used to compile the questionnaire that was sent to 500 individuals. The questionnaire was sent to consultants, construction project managers, architects and other professionals working in the European construction or real estate industry.

Finally, to answer the third research question a rough estimation of the unreported GHG emissions from a selected group of real estate companies was performed using a benchmark compiled for this research. The sustainability reports analysed in this study were gathered from the home pages of these companies if such report existed. Finally, a benchmark of buildings with green building certificates was used to compare the emissions from the selected companies. The benchmark was compiled in a web based life-cycle assessment tool.

1.4 Research Scope and Limitations

The geographical scope of the study was Europe. The companies from which the sustainability reports were analysed were listed real estate companies that follow some systematic guidelines of reporting like Global Reporting Initiative (GRI), Global Real Estate Sustainability Benchmark (GRESB), Carbon Disclosure Project (CDP) or European Public Real Estate Association (EPRA). The data collected from these reports was limited to GHG emissions and information on green building certificates as these provide proof of wider accounting of emissions.

The questionnaire was sent out to 500 construction and real estate experts that are in some way working with green building certifications. Due to their previous exposure they are more inclined to have a positive outlook towards green building certification systems and therefore

does not represent the views of the industry as a whole. Also the fact that only 41 individuals responded to the questionnaire adds to the potential positive bias.

Finally, the benchmark used for the estimation of the GHG emissions is compiled from certified buildings only and therefore do not represent the average emissions but rather the best-case scenario. The buildings are distributed through varying geographical locations and therefore the average values are not directly applicable to each and every climate conditions even within Europe.

1.5 *Structure of the Thesis*

The thesis is structured in five chapters. Chapter 1 provides a short background on the thesis topic, introduces the research questions, research methods and the scope of the research. Chapter 2 is based on the literature review. Each of the sub-topics introduces a separate theme that is relevant to the overall research and will help the reader in understanding the purpose of the research. Chapter 3 presents the research that addresses each of the research questions presented in Chapter 1. Chapter 4 presents the results of the research and finally Chapter 5 provides a conclusion and discusses any further research necessary in the field.

2 Literature review

This chapter introduces the topics relevant to the research questions that help the reader to understand the significance of each of the research questions. The first three sub-topics cover the importance of real estate in the overall GHG emissions and how it is both a major cause and a potential solution to reducing them. After that the relevant EU legislation affecting real estate industry is introduced. Finally, voluntary initiatives like green building certificates and sustainability reporting are discussed.

2.1 *GHG emissions and climate change*

According to IPCC (2007), Climate Change is “the change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity”. Which differs from some other definitions like the one used in United Nations Framework Convention on Climate Change (UNFCCC) which defines climate change as “the direct or indirect change in climate caused by human activity in addition to the natural variability” (UNFCCC, 2011). A single decade of unusually warm or cold weather does not provide enough evidence to prove climate change but as the Intergovernmental Panel on Climate Change (IPCC) bluntly states in the (2014a) report on Climate Change - every consecutive three-decade period has been warmer than the previous one since 1850. Since the overwhelming majority of scientists who contribute to IPCC reports (IPCC, 2017b) agree on this, we can, beyond reasonable doubt, be certain that global warming occurs, but what causes it?

Climate change is the result of intricate relationship between the emissions of carbon, the carbon cycle, biosphere and other factors (Malik, 2008, p1). The science behind it is beyond the scope of this work but it is essential to understand the basic concept of it. The main cause of the current global warming is the increase in anthropogenic greenhouse gas emissions since the dawn of industrial revolution. Among other gases Carbon Dioxide (CO₂), Methane (CH₄) and Nitros Oxide (N₂O) are the biggest contributors to the greenhouse gas effect (IPCC, 2014b p.4). To put this in perspective we can single out CO₂ as it is the most widely recognized greenhouse gas to understand its effects on the climate. To do this, all the other greenhouse gasses are equated in their potency relative to CO₂, and the total amount is referred to as CO₂-equivalent (CO₂-eq), which is widely known as the Global Warming Potential (GWP).

Before the industrial revolution, CO₂ levels in the atmosphere were between 270 and 280 parts per million (ppm) by volume (Malik, 2008). As reported by all major news outlets worldwide, in May 2013, the CO₂ levels in the atmosphere exceeded 400 ppm first time in several hundred millennia (European Environment Agency, 2013). This translates into the GHGs concentration in the atmosphere of 445-490 ppm of CO₂-eq. This is an important milestone in its most disparaging sense because the IPCC has recognized this as the threshold level for limiting the climate change to a 2-degree Celsius rise above the pre-industrial levels. The IPCC has set the limit of 2-degree rise in the global temperature during the 21st century comparing to pre-industrial level as the threshold for avoiding potentially irreversible and catastrophic changes to human society and the environment (European Environment Agency, 2008). As things stand now, we are already on track to reaching and exceeding this threshold. With no additional GHG mitigation initiatives, models show, that the average mean global surface temperature would increase between 3.7 and 4.8 degrees Celsius over the 21st century. This would lead to catastrophic and potentially irreversible climate change that would negatively affect biodiversity, ecosystem services and economic development (IPCC, 2014b). Sea level rise, extreme weather, flooding, food insecurity and loss of ecosystems are just few of the risks associated to climate change.

The implications of climate change go far beyond the natural environment. The economic cost of climate change is yet to be determined. There has been a lot of studies on the effects of climate change on certain industries but more recently more evidence has been brought forward to support an overall negative economic impact due to climate change. According to Burke et. al (2015) global economic performance is closely connected to climate change. The study speculates that unmitigated climate change could reduce the global GDP by up to 20% by the year 2100. Even if we do manage to limit the emissions and consequential climate change below the 2-degree Celsius limit, the IPCC (2014b) estimates the annual economic losses between 0.2% and 2% of the income. Furthermore, the extreme weather episodes will increase the losses and loss variability of physical capital (IPCC, 2014b).

2.2 GHG emissions from Built Environment

The most common thing that we hear about buildings and their effect on the environment is that they consume 40% of the global primary energy. According to the International Energy Agency (2013) building sector is the number one energy consumer globally and is an equally important contributor to the overall GHG emissions. In absolute figures, the building sector in 2004 was responsible for 8.6 Gt of CO₂ emissions or 33% of the total global emissions

(Levine et al, 2007). Therefore, it is clear that to avoid catastrophic climate change a lot of improvements are needed in the real estate industry.

The need for energy savings in the buildings is well recognized. The real estate sector is seen as a relatively low-hanging fruit and offers very cost-effective measures to reduce the energy consumption and the associated GHG emissions. This has triggered the rise of various energy efficiency standards worldwide (Cubi, 2011). However, the overall energy consumption in buildings since 1970 has increased by 1.8% annually (IEA, 2013). Just in last two decades, the primary energy consumption and the CO₂ emissions from the real estate sector has increased by 49% and 43% respectively (Perez-Lombard, 2008). However, without any energy efficiency measures, the OECD countries would have consumed 49% more energy than they did in this same time period (Geller et al., 2006). While energy consumption in buildings is growing globally, the increase in OECD countries is much lower than in other nations. The share of the energy generated using fossil fuels is also decreasing so some positive trends can be seen, but the overall picture is still worrying (IEA, 2013). In emerging markets, the annual growth of energy consumption is much higher at 3.8%. This means that in less than 20 years the energy consumption in these nations will double (Perez-Lombard, 2008).

In the EU, 38,5% of the total final energy was consumed by real estate in 2014, followed by transportation (33,2%) and Industry (25,9%). This translates into roughly 36% of total emissions (European Commission, 2016). Within the building sector, offices and retail/service buildings consume more than half of all energy or 26% and 28% respectively. Improvements in the building codes have played a role in reducing the energy consumption in residential buildings since 2007, while the energy consumption in non-residential buildings has remained stable. The economic crisis of 2008 in Europe had an influence on energy consumption in buildings as fewer new buildings were erected but also fewer buildings were retrofitted with more energy efficient installations (D'Agostino et al, 2016).

The emissions from energy consumption in the buildings depends on a multitude of factors like the use of renewable energy, district heating and cooling and the particular countries energy mix. In Europe, Norway has the lowest emissions (5 kgCO₂) per m² of floor area followed by Sweden (8 kgCO₂) and Switzerland (11 kgCO₂) while Luxembourg, Czech Republic and Ireland have the highest emissions of up to 120 kgCO₂ per m² of floor area. The huge discrepancy between the energy consumption and GHG emissions arises from the fact that Norway produces most of their electricity from hydroelectric power plants while Ireland is highly dependent on fossil fuels (Howley et al, 2015). This clearly illustrates the importance of renewable energy resources in reducing the overall GHG emissions from the real estate.

Many of the improvements, achieved in energy efficiency so far, come from improvements in technologies and wider adoption of the best available technologies. Developed countries have added energy efficiency to the building codes and nowadays cover, not only new buildings, but also renovations and refurbishments (UNEP, 2009). Improving the building envelope can reduce the energy consumption for heating and cooling by up to 30% and 40% respectively, adoption of efficient lighting technology can reduce the energy consumption for lighting by 40% and more effective appliances along with more effective fuels for energy generation can provide further improvements (IEA, 2013). The focus has largely been on the

operational energy consumption and for a good reason as it accounts for up to 80% of the total building lifecycle energy use (BIS, 2010).

What makes the improvements in energy efficiency particularly attractive are the cost reductions that some of them offer. Some of the existing technologies that has the potential to save energy has payback time as short as 4 years (Brown, 2009). There are however inherent barriers in the building sector to achieve energy efficiency such as the long lifespan of buildings and related technology, high initial cost, split incentives and the fact that the true cost of CO₂ is not reflected in the market price. (IEA, 2013) Furthermore, when a new building is commissioned the designers and procurers can even be penalized for more effective systems due to the increased initial cost (Brown, 2009).

While the biggest potential for reduction in energy consumption is in the use phase there are other stages in the buildings life-cycle that should not be overlooked. In broad terms, there are three main stages: construction stage, use-stage and deconstruction. An example of building life-cycle stages can be seen from the Figure 1 below illustrating the share of energy consumption in each of the stages.



Figure 1 Broad areas of a building's life cycle (BIS, 2010)

From the Figure 1, excluding design and use phase, all other phases can be considered as the embodied energy and carbon in the construction of the building. These are the emission that come from the raw material extraction, material production, distribution, construction process itself and the eventual demolition of the building, as well as, the treatment and disposal of materials after demolition (Anderson, 2012). It is common knowledge within the industry that the embodied carbon accounts for 20% of total while the use phase emissions account for the other 80% but this is changing (Herczeg et.al., 2014). In UK, for example, the capital or embodied carbon in new buildings account for 30-45% of the total carbon (Arup, 2015). The shift in importance of the different stages of the buildings' life-cycle is only natural as the old buildings are being refurbished and the new ones built according to new regulations (Anderson, 2012). With the gains in energy efficiency in the buildings and Europe moving towards near-zero energy buildings, the other phases of the building life-cycle are becoming more important (Herczeg et.al., 2014).

The production of construction materials requires extraction of natural resources, processing of these resources and transportation of the resources and ready materials to the place of use. The energy consumed during this process and the related CO₂ emissions are regarded as embodied energy or carbon (Hammond, 2008). In its most simple form, the embodied carbon of construction materials is the CO₂ emitted from burning of the fossil fuels to extract and process the raw materials into the final product and transport it to the construction site (Anderson, 2012). This is called cradle to gate approach but excludes important stages like construction phase, maintenance, refurbishment, demolition and disposal. A more comprehensive approach is the so-called *cradle-to-grave* approach which is a holistic

approach looking at the whole lifetime of the building. This includes the initial embodied carbon, the recurring embodied carbon from the refurbishment and maintenance and the end-of-life carbon from demolition and disposal of the waste (McAlinden, 2015).

The embodied carbon usually constitutes somewhere between 20% and 45% of the total energy consumption of the real estate sector (Herczeg et al, 2014). Even if, the lower value of 20% is considered in UK for example this amount to 8% of the total GHG emission of the country (Anderson, 2012). With the continuous trend of reducing the emissions related to the use phase the share of embodied carbon in the overall emissions can grow closer to 20% in Europe. Within the embodied carbon, over 80% of the emissions arise from manufacturing of the product with transportation, construction and refurbishment or demolition making up the other 15-20% (HM Government, 2010). Steel, aluminum and concrete alone are responsible for 68% of the total embodied energy in Europe (Herczeg et.al., 2014). However, this cannot be directly translated into embodied carbon as it depends largely on the energy mix for the production process of the materials.

When accounting for the embodied carbon, the geographical location of the construction as well as the countries, where materials are sources, need to be taken into account (Ünal, 2014). To illustrate this example, we can look at the aluminum industry. The CO₂ emissions from aluminum production in Europe are about 4.5 tons per ton of aluminum while in China the CO₂ emissions per each ton of aluminum are 9.1 tons. If we look at Norway, Brazil, Canada and Russia the emissions, from aluminum production, are significantly lower than the European average due to nearly 100% reliance on hydropower for electricity generation in aluminum industry (Bergsdal et al, 2004).

The US Energy Information Administration in their International Energy Outlook 2016 projects that the energy consumption worldwide will increase by nearly 50% by the year 2040 comparing to 2012. Renewables and nuclear energy, which are low in CO₂ emissions, are projected to be the fastest growing energy sources. However, fossil fuels will constitute 3 quarters of the total energy production. Most of this growth will happen outside Europe and the OECD countries. (EIA, 2016) In Europe, where the projections are very different, the economic growth of EU will become more and more decoupled from the primary energy demand. Due to improvements in energy efficiency, the overall demand for the primary energy in EU will decrease by 23.9% according to EU Reference Scenario (2016). The use share between the industries remains similar with residential and transport leading in consumption. (EC, 2016)

The total energy demand in residential sector will increase by 0.9% annually on average (EIA, 2016). While the absolute energy consumption in buildings will increase for the next few decades, it is estimated that, emissions will decrease due to existing mitigation measures and improvements in energy efficiency (EEA, 2015). Currently, the total primary energy consumption from buildings, including use phase and embodied carbon, accounts for approximately 40% of the total energy consumption. The share of energy consumption between use phase and embodied energy is however changing. (Cubi et.al, 2014) Moving to low energy buildings, using the best available technology and decarbonization of energy productions can have a significant impact on the future of carbon emissions from buildings.

Even with all the improvements in energy efficiency so far, if no further improvements are achieved the total energy demand is expected to rise by 50% by 2050. Same time it is

estimated that to remain within the 2° C threshold limit, the CO₂ emissions from the building sector need to be reduced by 77% in the same time period. (IEA, 2013) Even though the correlation between the rise in energy consumption and CO₂ emissions is not linear, there is a huge gap between where the sector is heading to and where it should be. In the last 30 years, the per capita energy consumption has risen by 15.7% while in the same time period the CO₂ emissions by 5% (Perez-Lombard, 2008). To narrow the gap a significant move towards renewable energy and the decarbonisation of power sector is necessary.

In Europe, where there are already many existing measures to decrease the GHG emissions from buildings and improve the energy efficiency, it is projected that with current measures in place the CO₂-eq emissions are going to decrease by some 18% by the year 2035 comparing to 2015 levels. If additional measures are introduced, the reduction in CO₂-eq emissions will increase to 23% in the same time period (EEA, 20125). Even though the GHG emissions in Europe are decreasing, the slow addition of new buildings to the building stock combined with low renovation rates will pose a challenge to achieving the goal of 27% improvements in energy efficiency by the year 2030. This is an important goal towards achieving the EU's emission reductions goal of 80% by the year 2050 (Artola et al., 2016).

The regional and local policies and regulations have had a positive effect on the GHG emissions in Europe. However, to get a complete picture of the GHG emissions caused by European industry, we must look at the Extra-EU trade in goods. The general approach is to look at the production based emissions but this does not account for goods produced in e.g. China and consumed in EU. Between 1990 and 2008 the reduction in GHG emissions in so called Annex B countries, referencing to Kyoto protocol, was lower than the increase due to imports from non-Annex-B countries. (Peters et al., 2011) If we look at the EU countries alone the consumption based emissions have decreased between 1995 and 2011 but by considerably less than production based emissions illustrated in the Figure 2 below.

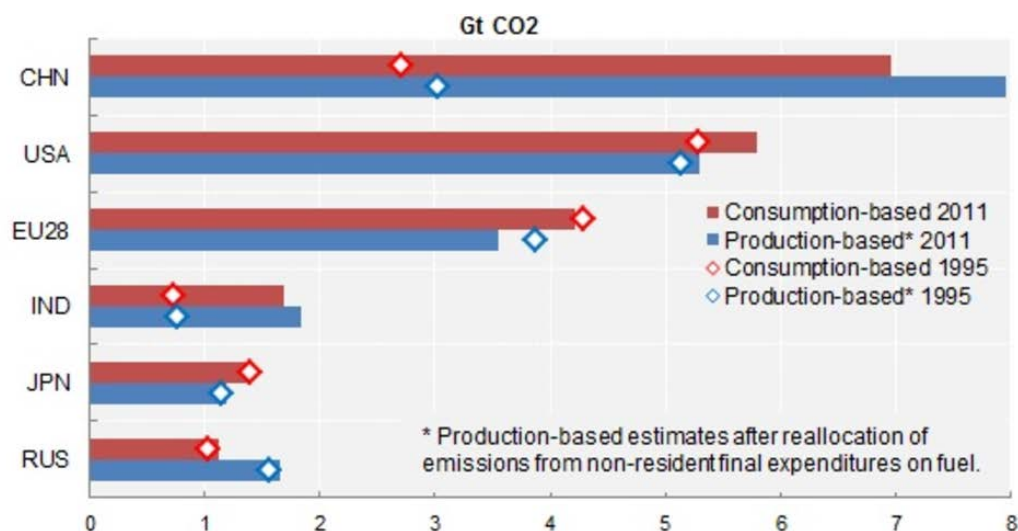


Figure 2 Consumption and Production based CO₂ emissions (OECD, 2015)

EU is the third largest player in international trade after United States and China. The total value of goods imported into Europe from non-EU countries was EUR 3 453 billion in 2016 (Eurostat, 2017). The net import of carbon has raised concerns about climate leakage that is offsetting the benefits of the policies within EU. Furthermore, if only the producers of certain goods within the EU will be obligated to pay for their carbon emissions they will lose the

competitiveness with non-EU producers leading to further increase in the imports of goods from outside (BIORES, 2011).

There is no reliable information on the exact amount of construction materials being imported into EU from non-EU countries. It is clear that Europe consumes more of some basic minerals used for manufacturing and construction such as iron and copper. Similarly, Europe imports majority of the rare earth elements such as cobalt, indium, lithium, platinum, tantalum. The complexity of the global trade and supply chains for manufactured products makes it very difficult to estimate the actual environmental impacts from the traded goods (Claire, 2014). Even if one attempts to estimate these emissions, there are no reliable data on the manufacturing process in the country of origin. So, the data would highly depend on estimations. One suggested way of tackling the carbon leakage is by introducing Border Carbon Adjustment (BCA) which would essentially be an import tariff on goods with high embodied carbon (BIORES, 2011).

2.3 Climate change effects on Built Environment

Based on reviewed literature, it is clear that the built environment has enormous impact on the GHG emissions and therefore the climate change. The effects are not a simple cause and effect equation, but there exists a positive feedback loop between the two. This is a phenomenon when the response to a change fuels the change itself. Global warming has the potential to exacerbate the urban heat island effect causing higher energy consumption and therefore higher GHG emissions from real estate in these areas. (Santamouris, 2014).

The urban heat island effect occurs when natural vegetation is replaced with heat absorbing materials found in buildings and pavements. This effect intensifies further when you consider the heat exhausted by cars and air conditioners. It is estimated that in the most populated cities the urban heat island effect could add an extra 2 degrees Celsius of warming to the already warming climate by 2050. This extra heat has the potential of causing an enormous economic burden in the form of additional energy demand, more polluted air and water as well as loss in productivity. (University of Sussex, 2017)

A research by Santamouris (2014) estimates that the cooling demand due to the heat island effect increases by 23% while the heating demand decreases by 19%. This corresponds to 11% of increase in the total energy demand for heating and cooling. This is further supported in a study by University of Sussex (2017), which claims that cities will have at least twice higher costs of climate change due to the urban heat island effect comparing to less populated areas.

There is no real effect on global warming caused by the urban heat island effect, however, it is important to understand the risks to the built environment that the global warming poses. The global warming that is largely caused by the same cities. There are various methods of mitigating the urban heat island effect but these require retrofitting of the buildings and other city elements such as infrastructure. The most effective way to prevent the risks posed by climate change is to prevent it to the extent possible while preparing for the mitigation necessary. (Grimmond, 2007)

Global warming is also associated with extreme weather event like floods, storms, tropical cyclones and draughts that can pose a further risk for built environment (IPCC, 2014). From

recent history, the two most memorable are hurricanes Irene and Sandy which each caused 56 and 131 human casualties and \$15,6 and \$63 billion in damages respectively (Rudman, 2013). In Europe, extreme heat wave killed 70 000 people, mostly elderly and infants. The historic location of cities near water for transportation now increases the risks of extreme weather and rising sea levels, it is estimated that 70% of the large European cities are vulnerable to sea level rise (World bank, 2013). If climate change in itself is not a good enough reason to decrease the emissions from built environment, then the risks to the built environment posed by the global warming should be.

2.4 EU climate related legislation

Today there are over 1200 climate related laws worldwide, in 1997 there were about 60. The rate at which these laws are passed has decreased considerably as more of the geographical area and aspects of climate change are covered by the now existing laws. The focus has moved now from passing new ones to strengthening the existing ones (Nachmany, 2017).

While climate related laws is a broad term and can also be related to climate change adaptation and mitigation, the fact that there are 17 emissions trading systems (ETS) in place today, demonstrates that countries are taking emissions related legislation seriously. The 17 ETS cover 35 different countries from which 9 are in Asia (ICAP, 2015). China is about to implement a national ETS in 2017 that will increase the total global GHG emissions coverage by an ETS from 9% to 18%. The total cap on emissions in the Chinese ETS is bigger than in all other ETSs combined but the implementation of any such system gives a momentum to emissions related legislation (Swartz, 2016).

As mentioned before the most notable achievement in recent years is The Paris Agreement that has been ratified by 156 parties. The agreement entered into force on 4th of November 2016 and is the most widely ratified legally binding agreement related to climate change mitigation. The Paris Agreement largely depends on Nationally Determined Contributions (NDCs) that are set by the member countries themselves but must be revised every 5 years. The agreement provides a framework for enhanced transparency and considers the capacities that each party has to contribute to the overall GHG emissions mitigation. To increase the flexibility of the agreement it not only supports collaboration and assistance between different countries but also between the private and public sector in form of transferrable GHG emissions (UNFCCC, 2015). While the Paris agreement provides an overall direction towards reducing GHG emissions, EU has already ratified many other legally bindings directives.

The European Union has decreased its emissions by 22% between 1990 and 2015 despite the fact that the EU's economy grew by 50% in that same time period. In 2015, EU was responsible for 10% of the total global GHG emissions, and to further reduce EU's impacts, a legislation is being put in place to achieve the commitments made in the Paris agreement to reduce emissions by at least 40% between 1990 and 2030. The focus of the new legislation is to expand the current EU ETS and impose binding GHG emissions targets to sectors outside of the ETS. (EC, 2017)

In November 2016, European Commission released a comprehensive report titled "Implementing the Paris Agreement Progress of the EU towards the at least -40% target" which details the progress so far and the actions planned for future. Each year the

Commission publishes climate action progress report and reports the progress to UN. GHG monitoring and reporting is therefore a key role for the Commission. The legislations that support these goals and emissions reductions within EU and are relevant for this work are: Industrial Emissions Directive, EU Emissions Trading System, Effort Sharing Decision and Renewable energy directive. All of these have direct or indirect effects on real estate by influencing the production of energy, production of materials and putting indirect cost on carbon emissions.

2.4.1 The Industrial Emissions Directive (IED)

The Industrial Emissions Directive (IED) is the main instrument for preventing and controlling the emissions from industrial processes in European Union. The directive was adopted in 2010 and came into force in 2011. Industrial processes are one of the biggest contributors to overall pollution in Europe and the IED aims to protect the environment and human health by controlling and reducing these emissions. (EC, 2016)

Under the IED industrial installations that cover activities in industries such as Energy industry, Production and processing of metals, Mineral industry, Chemical industry and Waste management among other industries. Installations that are covered by the directive must operate in accordance with the permits that are issued by the relevant authorities in the member states and follow the principles and provisions of the IED. (EC, 2016)

The IED is based on few key principles, namely: an integrated approach, use of best available technique (BET), flexibility, inspections and public participation. The permits take a comprehensive look at the overall environmental impacts of the installations by considering emissions to air, water and land as well as generation of waste, consumption of raw materials, energy efficiency, noise, prevention of accidents and site restoration. The permits and subsequent emission limits are based on the BET that are set by the member states. For some heavily polluting activities the emission limits are set on the EU level while in some cases some flexibility is allowed given that sufficient reasoning is provided. (EC, 2016)

2.4.2 Emissions Trading System (ETS)

Another fundamental tool in combatting the greenhouse gas (GHG) emissions in Europe is the EU emissions trading system (EU ETS) which is the first major carbon market in the world. The main principle of EU ETS is a cap and trade system where a cap of GHG emissions is set for the installations that are covered under EU ITS. This cap is lowered incrementally to reduce the overall emissions within all the installations covered by EU ITS. Within this cap, the companies purchase or trade the emission allowances. Each year the companies covered under EU ETS must submit enough allowance for all their emissions to avoid hefty fines. Companies that have spare allowances left can sell them to companies that have exceeded their allowances or keep them for years to follow. (EC, 2016)

The EU ETS has 2 clear benefits: it provides incentive for investing in clean and low- carbon technologies by putting a price on carbon and it allows for cutting the emissions in a flexible way. Unlike a tax on emissions, the possibility of trading the emission allowances under EU ETS means that the emissions are cut where it is the most cost effective. (EC, 2016)

The EU ETS operates in 31 countries and covers approximately 45% of the total GHG emissions in EU. Similarly, as with IED the EU ETS covers only a limited number of industries such as: power and heat generations, energy intensive industry sectors and aviation. The energy intensive industries include steel works, production of iron, aluminum, metals, cement, lime, glass and ceramics. The policy has been deemed a success by the EU due to 5% cuts in emissions since 2013 in the industries covered by EU ETS. The goal is to reduce the emissions from these industries by 21% in year 2020 compared to 2005 and by 43% in 2030. (EC, 2016)

While these EU directives and policies are great strides towards lower emissions from the industry within EU there are many experts who are concerned about the reduced competitiveness of EU manufacturers due to increased cost. Since there are no import tariffs on carbon from outside EU, manufacturers from outside EU have clear advantage. This advantage however can be offset by public opinion and national regulations on buildings that enforce more environmentally sound procurement process. For example a regulation mandating certain maximum level of emissions from materials would enforce a more environmentally responsible purchasing of construction materials and therefore offset the advantage that non-EU manufacturers have in price. (EC, 2016)

2.4.3 Effort Sharing Decision

The Effort Sharing Decision (ESD) is a binding annual GHG emission target for the member states that covers sectors that the EU ETS does not cover like transport, buildings, agriculture and waste. The ESD takes the year 2005 as the base year and sets rules for how the annual emission allocations (AEAs) between year 2013 and 2020 are to be set. The AES are set based on the Gross Domestic Product per capita of the member state. The range varies significantly from 20% decrease in emissions by 2020 compared to 2005 for the richest member states to 20% increase for the poorest member states. (EC, 2017)

The different GHG reduction targets for different countries and in some cases even an increase in the total emissions are applied to account for the level of economic growth expected in the country. The targets are set based on business as usual scenario so the level of commitment from each member state is equal. By 2020, collectively the ESD should achieve a 10% reduction in GHG emissions from the sectors covered by the legislation compared to 2005 levels. (EC, 2017)

The ESD uses a mix of both EU level measures and member state set targets. Essentially, most of the responsibility falls on the member states to define national measures and policies to reduce the GHG emissions to the AEAs set targets. This means that the member states have the flexibility to choose the most appropriate mitigation mechanism for their conditions. Real estate is just one of the areas where the reductions can be implemented. (EC, 2017)

2.4.4 Renewable energy directive

The EU Renewable energy directive (RES) provides policy and promotes the use of renewable energy resources to achieve a share of 20% of the total energy demand by 2020. This directive as many others is based on the individual targets of the member states but requires a minimum of 10% of transport fuels to come from renewable resources. (EC, 2017)

The motive for this directive is to reduce the GHG emissions, while promoting energy security and efficiency. Under the directive each member state sets their own national action plans that depend largely on the states capacity to move towards renewable energy. The Norwegian national target for example is 67,5% use of renewables while UK and Italy's targets are below the overall target of 20% share of renewables. (Lind, 2013)

2.5 Real estate specific legislation

All of the above discussed legislations are very closely related to the built environment. The built environment is responsible for a large share of the energy demand and is responsible for almost as large share of the GHG emissions in Europe and therefore some of the improvements will have to come from real estate sector. Two of the most important pieces of legislation that directly relate to energy consumption in buildings are Energy Performance of Buildings Directive and Energy Efficiency Directive.

As can be deduced from the names of these directives both of them focus heavily on the energy efficiency in the buildings and not on the emissions from other stages of buildings life cycle. In addition to these directives the European Commission also publishes a database - EU Building Stock Observatory to track the energy performance of buildings across Europe. (EC, 2017)

2.5.1 Energy Performance of Buildings Directive

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings is the key legislative tool to improve the energy efficiency of the buildings. The directive takes into account the outdoor climate and local conditions as well as the indoor climate requirements and sets a cost-effective targets of energy efficiency in new and retrofitted buildings in the EU. The directive provides a framework for the member states to set minimum energy efficiency targets that are cost-optimal. (EP, 2008)

In addition to the minimum energy efficiency requirements, all new buildings under the directive must consider the economic, environmental and technical viability of alternative systems such as decentralized renewable energy sources, cogeneration, heat pumps and district heating especially if it is based largely on renewable energy sources. For existing buildings, the minimum required energy performance must be considered when major renovations are undertaken or an element that has a high impact on energy efficiency is being replaced. These requirements can apply to a renovated building as a whole, a unit of the building undergoing renovation or a building element being replaced. Same consideration must be applied to technical building systems such as heating systems, hot water systems,

air-conditioning systems and large ventilation systems when new ones are taken into use or being replaced or upgraded. (EP, 2008)

The directive also states that all new buildings must be nearly zero-energy buildings by 31st December 2020 and that all new buildings occupied or owned by public authorities must be near zero-energy buildings by 31st December 2018. Large part of the legislation regarding the near-zero energy buildings relies on the Member states to come up with definitions and policies to reach these goals that are then reviewed by the Commission. (EP, 2008) The Energy Performance Certificate (EPC) is an important tool in communicating the energy efficiency of the building and must be presented to all new buyers or tenants of buildings. The EPC must contain the energy performance of the building in question as well as the minimum performance requirement. In buildings where more than 500 m² are occupied by public authorities the certificates must be displayed publicly.

2.5.2 Energy Efficiency Directive

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency is a binding measure to reach the 20% improvements in energy efficiency by 2020. It states that all Member countries must use energy more effectively in all stages of the energy chain. This directive is not purely aimed at the buildings but the policies are very closely related to the built environment. (EC, 2017)

The directive states that energy distributors or retailers of energy within the Member states must achieve a 1,5% savings in energy by implementing energy efficient measures. However the countries can opt for substituting this efficiency gain by improving the efficiency of heating systems or the building envelope. The governments should buy only energy efficient buildings, products and services and are obligated to perform renovations on at least 3% of the buildings they occupy or own to improve the energy efficiency of such building. (EC, 2017)

In addition to building energy efficiency the directive states that countries should promote cost-effective energy audits for small and medium companies while large companies are obligated to complete such audits. On a consumer level there should be easy and free access to data such as energy consumption through individual metering. (EC, 2017)

2.6 Green Building Certificates

In addition to legally binding directives there are many different standards and certification systems that aim at reducing the operational, embodied or total energy consumption of the buildings. Some of these standards are international and well recognized within the industry while some of them are regional or national. Most of the obligatory standards focus only on the operational energy of the buildings like the European 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive introduced above. Many of the voluntary certificates address this limitation.

The certificates that include the embodied carbon or look at the whole building lifecycle emissions are purely voluntary, however, there are certain market drivers that encourage the

adoption of these standards (Deutsche Bank Research, 2010). It has been long debated, whether mandatory regulations or purely market driven incentives are the most effective way of reducing the GHG emissions from real estate. In Europe, a mix of EU directives, mandatory local legislation and market driven voluntary building standards tackle the issue (Fuerst, McAllister, 2011). The benefits from green building certificates can be divided into three main domains: Environmental, Economic and Social. Each of these benefits are important to different stakeholders, however, they are all interlinked. The social and environmental benefits to large part contribute to the economic benefits which are important for the decision makers in the real estate sector (Zuo, 2014).

According to Kats (2003) the financial benefits from green building certificates include: “energy and water savings, reduced waste, improved indoor environmental quality, greater employee comfort/productivity, reduced employee health costs and lower operations and maintenance costs.” According to analysis of 60 LEED certified building, the energy savings in these buildings ranged from 25% to 30% comparing to non-certified buildings. Furthermore, the certified buildings did not experience the same peak hour energy demand further adding to the cost savings. (Kats, 2003) It is true that green buildings have a bigger up-front cost during the construction phase but this is largely offset by the cost savings during the life-cycle of the building (Zuo, 2014). Further benefits of green certificates are illustrated by a study from London where Chegut et al. (2013) found that BREEAM certified office building offered a rent premium of 19,7% and a sales transaction premium of 14,7% relative to similar non-certified buildings.

The environmental benefits of green building certificates depend on the particular certificate as their scopes vary. Responsible land use or reclamation of brown sites, reduction of construction and demolition waste, higher recyclability of materials and of reduction of GHG and other emissions from the construction and use phase of the building are among the benefits (Zuo, 2014). The already mentioned 25-30% decrease in operational energy demand will translate into significant reduction in GHG emissions from the use phase. Also depending if the certification scheme considers the embodied carbon in construction materials further reduction of GHG emissions can be achieved (Vierra, 2016).

Finally, the social benefits from green certificates come in the form of quality of living or working environment, occupational health and safety, productivity and health. Better indoor air quality, better lighting and improved comfort can all lead to better health and productivity of the inhabitants or employees of the building. Some building certification schemes also look at the harmful pollutants like VOC's in the building that can pose significant health risks. Due to improved health and productivity it has been speculated that employers can also attract more dedicated workforce. (Kats, 2003)

2.6.1 Types of Green certificates

Broadly speaking there are two types of green certificates and labels: single attribute and multi attribute. The single attribute certification systems look at a single aspect such as energy or water consumption while the multi attribute certification systems usually look at the whole life-cycle of the building. The multi attribute certification systems require an integrated design approach that looks at all of the building life-cycle stages discussed in chapter 2.2. Energy Star is a popular example of a single-attribute label while well know

certification schemas such as BREEAM, LEED and DGNB are multi attribute. (Vierra, 2016)

For the purpose of this thesis the pros and cons of the different standards and certificates are beyond the scope however it is important to understand the basic differences between them. In Europe, there are many different certification systems available. There is considerable variety between these systems and their coverage of different aspects of building life-cycle. Most of these systems have certified buildings only within their home country. This variability between the different systems make it difficult to compare building between countries and between different certification systems. However, there are some certification systems that have crossed the national boundaries and offer tools that are to some extent comparable even between these systems. (Vierra, 2016)

Probably by far the most well-known certification system is LEED, or “Leadership in Energy and Environmental Design”, developed by the US Green Building Council. LEED is closely followed by BREEAM in its popularity, which is developed by the UK based BRE Global and is well recognized in the UK and most European countries. Finally, DGNB, the German based certification system has gained some grounds as many national organizations have adopted the standard with slightly differentiating criteria. (Nelson, 2010)

The operational energy standards usually compare the buildings energy performance against a certain reference building. These relative performance standards use energy simulations to analyze the improvements of the energy efficiency in comparison to the reference building. Other standards look at the absolute energy performance of the building and have certain threshold for satisfying the standards requirements. One such well known standard is the “Passivhaus standard”, which requires the total energy consumption for the hot water, electricity and heating to be below 120 kWh/m² per year. (Cubi et al, 2011)

Certification systems like BREEAM, DGNB and LEED have taken a more comprehensive approach to the assessment of buildings by considering more aspects such as energy, water, materials and sociocultural aspects. In recent years, there has also been a shift towards a more scientific approach to evaluating building performance through Life-Cycle Assessment (LCA). While LCA is still not a requirement in many of the certification systems it has increased its importance in the overall certification. (Vierra, 2016) Most of the green certification systems go beyond GHG emissions and look at other impacts caused by the buildings like Acidification, Eutrophication, Depletion of the stratospheric ozone layer, Formation of tropospheric ozone and Depletion of nonrenewable energy resources. (LEED, 2016).

2.6.2 Life-Cycle Assessment

As discussed before, the building life-cycle consists of many stages starting from mining and manufacturing the construction materials, constructing the building, using the building and finally demolishing it and disposing or recycling of the deconstruction waste. There are direct emissions from the construction process, use of the building and demolition and indirect emissions from mining and transporting of raw materials, manufacturing of final construction products and their transportation to the construction site. Life-Cycle

Assessment is a systematic and comprehensive method that evaluates the energy flows, material consumption and the release of wastes through all stages of a buildings life-cycle. (Rashid and Yusoff, 2015).

Other measures aimed at reducing the negative environmental impacts focus on one or few aspects of the building, disregarding the effects these measures might have on other aspects. During an LCA the materials used, construction practices employed, the operational requirements as well as the end-of-life of the building are analyzed all in unison (Ünalán, 2014). Buildings have a relatively long life-span making it even more crucial to understand how the decisions made now will affect the emissions 50 years in the future (UNEP, 2009). There can be tradeoffs like increase in embodied emissions that lead to a greater saving in the operational phase, however only by looking at the whole lifecycle of the building we can see how design choices can affect the emissions in each stage and in total.

LCA, as a method, looks at the building environmental burden beyond just CO₂ and looks into resource depletion and even human health. The big advantage is that by holistically assessing the impacts throughout the life-cycle the problem-shifting from one stage to another or from one impact to another can be avoided. Furthermore, this prevents countries from shifting the emissions to other countries by importing large amounts of the construction materials (Buyle et al, 2013). LCA is a crucial tool in reducing the environmental impacts from building sector. If the GHG emission reductions goals are to be reached the first step is full disclosure and transparency. LCA provides a great tool for this purpose.

LCA provides a systematic and scientific analysis of the environmental impacts to the involved parties such as architects, engineers, developers and decision-makers. In the absence of LCA, the decisions will most likely be made based on the up-front cost of the project (Rashid, Yusoff, 2015). According to Säynäjoki et.al. (2017): "The building and construction industry provides a useful example of an industry with an acute need for reliable and comparable information on a life cycle's environmental impacts in order to support decision making." Performing LCA can be coupled with Life-cycle costing analysis to consider economic impacts of the building in addition to environmental and social ones. This approach can provide the best balance between environmental impact reduction and cost-effectiveness (Basbagill et al, 2013)

Large part of the emissions in real estate occur indirectly throughout a complex supply chain, additionally they occur slowly over the life-time of the building further complicating the information gathering. Despite the fact that buildings are responsible for nearly 40% of the GHG emissions they are not covered by the EU ETS. The existing directives of the EU focus heavily on the use phase of the buildings, disregarding completely the other stages that might account for up to 50% of the total emissions. (Säynäjoki et al., 2017)

The study by Säynäjoki et al. (2017) concludes that due to multitude of issues the results from different LCA studies had wide variety between results making it's usability limited. A large discrepancy was identified between the share of impacts caused by embodied carbon comparing to use phase. This discrepancy can be attributed to inconsistent methodologies and guidelines. This is further exacerbated by the practitioner's interpretation of the guidelines. The complexity of buildings means that there has to be a certain cut-off criteria to which elements of the building are analysed in the LCA which can lead to significantly varying results between the studies. (Säynäjoki et al., 2017)

2.6.3 EU framework of core indicators for buildings

The EU has identified a need for a common EU level approach to assessing the environmental performance of building to drive improvements in the performance and allow comparison between buildings. This awareness has driven the development of Common Framework of Core Indicators for the building performance. A study was initiated in 2015 to develop the framework that would be flexible enough to be used in existing certification schemes or on its own. The purpose of the common indicators is not developing a new certification scheme but rather to provide a voluntary framework of reporting the building environmental performance within the EU building sector. This framework could be used by various stakeholders such as public authorities, design teams and property investors. (Dodd et al, 2016)

The framework focuses on residential and office buildings within EU as these represent the vast majority (86%) of floor space in Europe. Six macro-objectives have been identified as the bases for the framework for common indicators that all concern: “An environmental, resource efficiency or functional performance aspect of significance to the life cycle environmental performance of buildings at EU level.” These macro-objectives were developed based on the current reporting tools that are adopted by the market and an LCA study identifying the most significant environmental impacts of the building life-cycle. The six macro-objectives identified by the framework are: Greenhouse gas emissions from building life cycle energy use, Resource efficient material life cycles, Efficient use of water resources, Healthy and comfortable spaces, Resilience to climate change, Optimised life cycle cost and value. (Dodd et al, 2016)

The first three objectives are focusing on the LCA of the buildings while the latter three are more concerned with the quality. Previously the EU has focused on energy use only while the more comprehensive environmental assessment was performed as part of voluntary certification systems. These objectives change that and lay a groundwork for EU policy that focuses on impacts beyond energy. (WGBC, 2016) This framework together with the voluntary certification systems already provide data that could be directly reported in the sustainability reports by the real estate companies.

2.7 Sustainability reporting in built environment

Every company is part of the community it operates in and even if we consider a company being purely profit driven it must ensure that its operations support the same community it depends on for the profits (Mulder, 2006). To be truly successful a company must balance between short term profits that support their operations and long-term optimization that ensures the sustainability of the company. Sustainability reporting is the practice of conveying the companies environmental, social and governance information to its stakeholders. In some companies, this is part the Corporate Social Responsibility (CSR) reporting while some companies choose to produce separate reports on their sustainability performance. (Wensen et al, 2011)

Sustainability reporting is a tool for companies to account for, disclose and take responsibility for their environmental, social and economic performance. Europe has the most advanced sustainability reporting practices in the world however even here they differ between different states and industries. In the last two decades, the amount of companies

employing some level of sustainability reporting has significantly increased. For large multinationals, it has become a norm to publish such reports. The reasons for reporting vary from simply complying with regulations to improving internal processes through accountability. There is a general call for a transparency which Wensen, et al (2011) illustrates by the growing demand of transparency in pension funds by the trade unions representing the very workers whose money is being invested. This clearly shows that people are preferring to invest in sustainable companies. (Wensen et al, 2011)

Similarly, to the building industry itself, this interest in sustainability reporting has spurred a rise in number of different ratings, rankings and indicators that measure the sustainability performance of a company. Stakeholders of these companies are becoming more and more reliant on these sustainability reports in their decision making to invest, purchase or seek employment from. (Wensen et al, 2011)

Unlike in financial reporting, where there are strict rules and regulations on the reporting, the corporate sustainability reporting does not have such oversight. The nonfinancial information that these reports contain is generally aimed at various stakeholders as a means of assurance of the company's effectiveness in managing the risks to satisfy these stakeholders. While the corporate sustainability reports do have the potential to effectively inform the stakeholders, the absence of standards for reporting raises concerns over misrepresentation of information. There are organizations such as The Global Reporting Initiative (GRI) that sets standards for companies that choose to follow their guidelines. CSR's that do comply with GRI guidelines are therefore considered more trustworthy. (Ballou, Heitger, 2005)

A study examining the effects of mandatory reporting in China, Denmark, Malaysia and South Africa (Ioannou, Serafein, 2017) found that the regulations significantly increased the disclosure comparing to non-regulated companies. While one of the major concerns of mandatory CSR are the externalities mostly in form of additional cost the study found that on average the effect of the regulation was positive on the economic performance of the company. In addition to economic benefit the credibility and comparability of the CSRs improves with common mandated guidelines. (Ioannou et al., 2017)

While the amount of companies issuing CSR reports has increased significantly the lack of guidelines make it difficult to compare the sustainable performance of two similar companies. It is important to define the significant indicators sector-by-sector to allow for this comparison and ensure that relevant information is reported. In real estate, it is valuable to discuss the emissions from buildings while for other industries the key indicators might lay elsewhere. (JLL, 2014) GRI refers to these as the material impacts and defines them as: "those that reflect an organisation's significant economic, environmental and social impacts, or substantively influence the assessments and decisions of stakeholders." (GRI, 2015)

Even with the considerable improvements in the numbers of reports in Real Estate sector there is a lack of relevant real estate disclosures. The general knowledge improvements in the industry among building specialists does not translate into updated disclosures based on this knowledge. The still relatively low disclosure among real estate companies, illustrated in Figure 3, can be explained by the overall reluctance of companies to disclose any information if not absolutely required to. (Eccles, 2012)

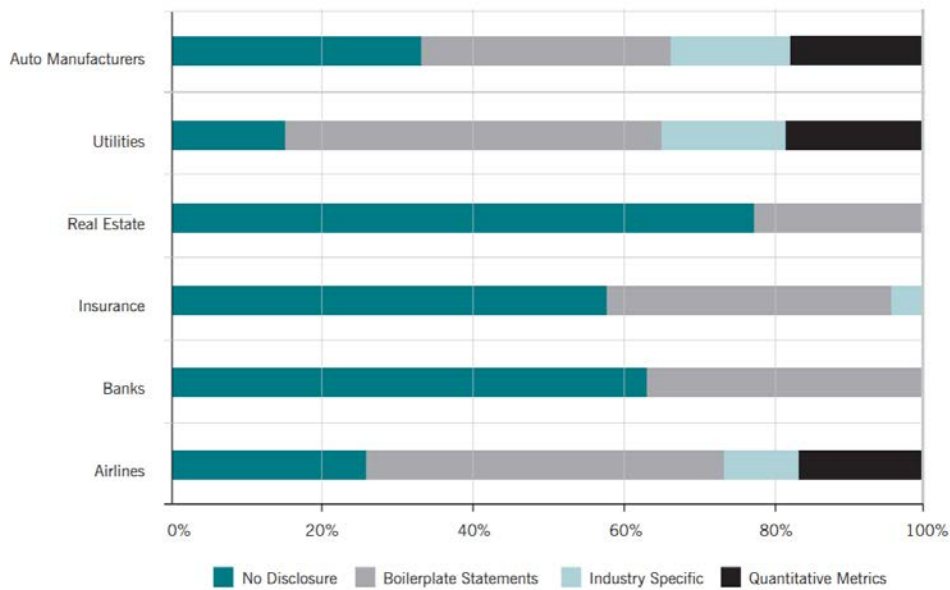


Figure 3 Climate Change-Related disclosure in Six Industries worldwide (Eccles, 2012)

The most common themes among the CSR reports in real estate and construction industry are prevention of CO₂ emissions, waste minimization, water conservation, ecosystem conservation and better selection of materials. A lot of emphasis in these reports is on the performance measures such as GHG emissions, water, electricity, fuel, natural gas and heating oil consumption. (Lamprinidi, Ringland, 2008) These are all relevant topics to reducing the GHG emissions and other forms of pollution however there is a lack consistency of what exactly is in the scope of the report. In real estate sector, the CSR is not shaping the goals and missions of the companies but are rather measuring and reporting the impacts (World Economic Forum, 2016).

In recent years, there has been a lot of development into standardized reporting including a EU Directive on the Disclosure of Non-financial and Diversity Information by Large Companies and Groups (JLL, 2014). There are multiple initiatives aimed at real estate sector that aim to solve the issues mentioned before, such as Urban Land Institute – Greenprint, Global Reporting Initiative – Construction and Real Estate Sector Supplement (GRI – CRESS), United Nations – Principles for Responsible Investment (UN PRI) and Carbon Disclosure (CDP). The European Public Real Estate Association (EPRA) has published Sustainability Best Practice Reporting Recommendations that are specifically aimed at Real Estate sector and so has European Association for Investors in Non-Listed Real Estate Vehicles (INREV).

The development in guidelines has led to an increase in sustainability reporting among real estate companies. The number of companies and funds that produce a separate sustainability report has increased both between listed and non-listed ones. Some 69% of EPRA members and 40% of European INREV members publish sustainability information on their website, while the number of members producing a dedicated sustainability report is 34% and 13% respectively. The quality of these reports varies largely but the above-mentioned sector specific guidelines have provided the materiality perspective. Furthermore, almost half of EPRA members and 22% of INREV members demonstrates path towards an integrated reporting, integrating sustainability aspects in their business model and strategy. (JLL, 2014)

GRI is one of the best-known organizations that provide voluntary guidelines to businesses, governments and other organizations to help them produce sustainability reports. GRI was created in 1990s and therefore is also one of the pioneers in sustainability reporting. (Brown, 2009) Their mission is to: “create a future where sustainability is integral to every organization's decision-making process.” (GRI, n/d) And the core beliefs of the organization are as follows: In the power of a multi-stakeholder process and inclusive network, Transparency is a catalyst for change, Our standards empower informed decision making, A global perspective is needed to change the world and Public interest should drive every decision an organization makes. (GRI, n/d)

GRI has a specific guidelines of sustainability reporting in different sector including one for Construction and Real Estate. The specific guidelines for emissions reporting are divided in three scopes that align with both the GHG protocol and ISO 14064 standard that are used for emissions reporting in corporate business. The reporting of GHG emissions is divided in three scopes: direct GHG emissions, energy indirect GHG emissions and other indirect GHG emissions. (GRI, 2015)

2.7.1 European Public Real Estate Association (EPRA)

EPRA is a non-profit association working towards greater investment in listed real estate in Europe. According to them, they achieve this by fostering trust and committing to full transparency. Its operations are based on working committees that bring together industry experts from different countries from which one is Sustainable Reporting Committee. Members of the association represent EUR 250 billion worth of real estate assets. The majority of the member companies are listed on the public stock exchange. (Epra, n.d)

EPRA produces Best Practices Recommendations on Sustainability Reporting (sBPR) that provide the members guidelines on reporting and holds awards for the companies that produce the best reports to raise awareness about sustainability reporting in the industry. The sBPR guidelines are largely based on the Global Reporting Initiatives GRI G4 CRESSD guidelines. The guidelines consist of core recommendations that apply to all members of EPRA and additional recommendations that are voluntary. The guidelines provide detailed description on how to report on various use phase related sustainability aspects including the GHG emissions from direct and indirect energy production. The EPRA guidelines do not provide any guidelines on embodied carbon emission reporting from real estate. (Epra, n.d)

2.7.2 Global Real Estate Sustainability Benchmark (GRESB)

GRESB is a real estate investor driven organization that aims to transform the way environmental, social and governance performance is assessed in real estate sector. The organization has more than 250 members including large pension funds. GRESB collects data on various real estate vehicles that can be then used by their members in order to optimize the risk and return of the investments. (GRESB, 2017)

The GRESB real estate assessment guidelines rely on 7 key aspects of performance and an additional assessment addressing new construction and major renovations. The seven key aspects plus the one additional are: Entity and Reporting Characteristics, Management,

Policy & Disclosure, Risks & Opportunities, Monitoring & EMS, Building certification, Stakeholder engagement and New construction & Major renovation.

Under the Monitoring & EMS aspect there are performance indicator that collect numerical data on energy and fuel consumption among other use phase activities that lead to GHG emissions. The Building certification aspect and additional aspect on New construction & Major renovation both inquire about embodied carbon and whether it is considered but there is no requirement to provide any actual figures. (GRESB, 2017)

2.7.3 Risks and Challenges in Sustainability Reporting

Large institutional investors are requiring more and more transparency in the sustainability performance of the portfolios they intend to invest. Portfolios with poor transparency in sustainability performance are seen as risky investments and analysis of the risks associated with sustainability are often performed to support the decision-making. The investors are pushing for lower GHG emissions, higher energy efficiency, reduction in water usage and improved waste management. (Deloitte, 2014)

Even though the investors are asking for more transparency and better environmental performance from the real estate companies according to JLL's Global Real Estate Transparency Index (GRETI) (2016) the progress in sustainability transparency has been slow. The report identifies carbon reporting as an especially critical gap. Only 4 countries worldwide have mandatory obligation for reporting carbon emissions and seven have voluntary frameworks for reporting carbon emissions. The lack of such frameworks or mandatory requirements in other countries demonstrates the lack of action in real estate sector towards efforts of reducing GHG emissions. The average rating score from GRESB benchmarking tool stands at 56 out of 100 points which is comparable to the GRETI index of 2.99. While the recent trend of both of these measures has been positive, the highly average score shows that there is still a lot of room for improvement in the sustainability reporting performance of real estate. (JLL, 2016)

The lack in sustainability reporting can also be attributed to an underlying issue that has been identified as Vicious circle of blame. In this circle of blame, each of the involved stakeholders point to another involved party as the reason for lack of sustainable practices but does not do anything to address the issue. This arises from the mixed interests that each of the involved parties has in the real estate sector. The concept is illustrated below in the Figure 4. (Baas, 2013)

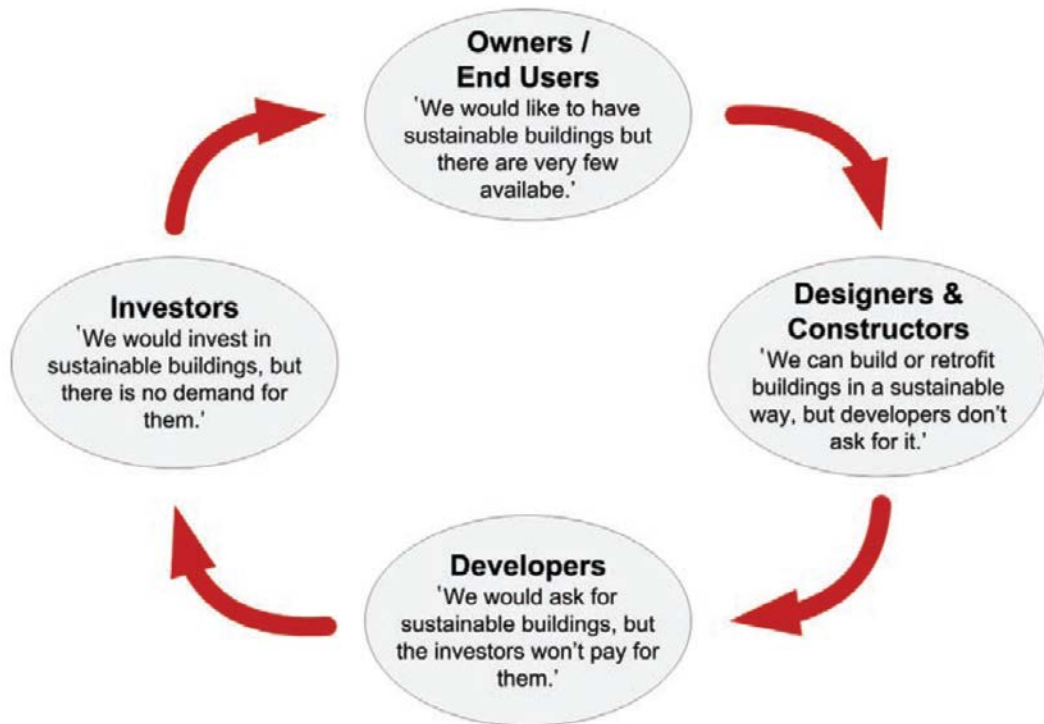


Figure 4 Vicious circle of blame (Fibre, 2008)

An annual report from Regional REIT (2015) states that: “The Company is a REIT and so its own direct environmental impact is minimal. The Group has no greenhouse gas emissions to report from its operations, nor does it have responsibility for any other emissions producing sources.” While not directly putting blame on the other involved stakeholders from this statement it is obvious that further improvement in the attitudes of some stakeholders is necessary. This also illustrates a similar problem in the reporting of sustainability performance where the burden of reporting is similarly shifted from one stakeholder to another.

As discussed earlier most of the attention in reporting of GHG emissions in real estate is focused purely on the operational emissions. However, not accounting for materials that the buildings are built from ignores large part of the real estate value chain. This prevents an effective communication between the construction industry and the real estate sector therefore limiting the potential improvements in the environmental performance of the real estate. (WBCSD, 2016)

Considering the complexity of a large real estate project and the number of components a project like that has, it is inconceivable that a full LCA could be performed or comprehensively reported by companies (Säynäjoki et al., 2017). One of the biggest barriers of integrating life-cycle assessment thinking into real estate is the lack of consistency between different LCA indicators making the information flow challenging. While there are many comprehensive indicators that can be used for LCA there is no single simple guideline of how the LCA performance data should be communicated to the stakeholders. The Common EU framework of core indicators for the environmental performance of EU buildings is one initiative that is attempting to solve the problem of communicating the LCA results within the industry. (WBCSD, 2016)

3 Empirical research

This chapter explains the methodology used to answer the research questions and the data collection processes. This thesis was conducted by using mixed method research and internet survey. The data was collected from sustainability reports, internet questionnaire and LCA results.

3.1 *Methodology*

To answer the research questions, proposed in the Chapter 1, a mixed method of research is utilized. The quantitative method is used to gather data from secondary sources and a mix of both methods is used to collect data from primary sources. The empirical part of this study consists of data collection from real estate company Corporate Sustainability reports (CSR), a survey of 41 building sector specialists and a data collection from LCA reports that would serve as a benchmark.

3.1.1 Mixed method research

Mixed method research combines both qualitative and quantitative research methods and therefore, compliments each other by taking advantage of strengths that each method possesses. The qualitative data that is collected alongside the quantitative data can help interpret the data better. The data collected through the mix of the both methods can also be used sequentially, so that findings of one method lead to the second method. (Ostlund, Kidd, Wengstro, Rowa-Dewar, 2010)

The study also mixes both primary information sources and secondary information sources. Secondary information sources are sources where the information has already been compiled by someone and stored in some accessible form. Sources that are considered secondary, include reports, studies, as well as books and articles. Usage of these sources are almost always necessary before conducting primary research. (Stewart, Kamins, 1993) Unlike the literature review, the secondary study in the empirical part uses a more systematic approach.

3.1.2 Internet survey

Paper based questionnaires in general get a better response rate than internet based ones but internet adds a level of convenience that the old method cannot. There are two main ways to distribute an internet based survey, one option is to send the survey form in the email while the other option is to compile the survey in a web based platform. These platforms provide a link to the web survey that can be then sent out to a large audience. (Fowler, 2013)

Even though it is reported that paper questionnaires get a better response rate, an internet based questionnaire was chosen for the pure convenience of it. The paper questionnaires are something of the past and therefore, Google forms was used to distribute the questionnaire. The questionnaire was sent to 500 construction sector specialists using Mailchimp as a tool.

3.2 Data collection

3.2.1 Collecting data from CSR reports

A list of European listed real estate companies was obtained from S&P GLOBAL (2016) coverage list, which is the most extensive list available for listed real estate companies in Europe. This list provides the names of the companies and stock exchange, in which it has been listed. The stock exchange country, in which the company is listed, is assumed to be the country from which the company is operating from. The names of the companies are used to find their webpages for further information gathering.

The web page and the annual or CSR reports were examined to gather the following information:

- Whether the company is only an investor or investor developer
- The approximate value of the company's portfolio
- Lettable area in portfolio
- Whether the company use CSR
- Framework used for CSR
- Reported GHG emissions for year 2016
- Whether the company owns certified buildings
- Any additional information regarding emissions reporting

For the purposes of reporting GHG emissions from other than use phase of the building, it is important to understand the core strategy of the company and whether it only purchases and holds real estates or is also involved in the development of real estate. GRI has a concept called materiality, which refers to the threshold at which some aspects become important enough that they should be reported. For sustainability reporting these aspects go beyond the economic ones and should consider social and environmental ones as well (GRI, 2017).

The approximate value of the portfolio and the lettable floor space area was gathered to get an understanding of the size of the company. The size of the company can be an indicator of its maturity and available resources, this in turn can explain the level of non-core activities such as sustainability reporting. The type of investors and their requirements for different sized companies likely vary as well.

Finally, it was examined whether the company has a form of CSR. First, the web page was examined for any information regarding sustainability and if available, the specific CSR report was downloaded. If there was no available information regarding sustainability in the web page or there was no report specifically for CSR then the annual company report from the latest available year was downloaded. Many companies choose to have an integrated reporting and therefore the sustainability issues are part of the larger report.

From the CSR report, a limited number of data was collected. It was examined whether the report follows a common reporting framework, such as GRI G4, GHG protocol or guidelines by EPRA. After that, the amount of reported GHG emissions for the last reported year was gathered if available. It was examined, whether the company has green building certificates

and what certification programs have been used. Additionally, any mention of emissions beyond the use phase was noted.

3.2.2 Internet survey

The questionnaire was designed in collaboration with 2 other students, doing research for their bachelor thesis, in various field of studies and Bionova Oy, which is a leading provider of Life-Cycle Assessment tools for buildings and building products. Due to this collaboration, there are sections of the questionnaire that are not directly relevant to this study.

The questionnaire is titled “State of the Construction Sector Life-Cycle Assessment” and consists of 4 sections. The first section introduces the study and tells the respondents the purpose of the study as well as the people behind it. The second section of the questionnaire asks from the respondents their basic information such as age, job position, company of employment, field of business and their level of familiarity with LCA.

The third part of the questionnaire goes more into the reasoning behind performing LCA in the construction industry and what are the perceived benefits of LCA. This part also attempts to quantify the benefit that LCA provides in a number of aspects important to real estate industry. The fourth and last part focuses on different tools used for LCA and the level of satisfaction with these tools. While this part is not directly relevant to this study it can give insights to factors that prevent a wider adoption of LCA in construction and real estate industries.

3.2.3 Certified building GHG emissions benchmark

To estimate the part of unreported emissions in the real estate industry a benchmark was created from buildings with green certificates. This is done using the tool called “One Click LCA”. To create this benchmark 20 properties that have achieved LEED or BREEAM certification and performed an LCA in the process of certification are selected. Any obvious outliers, like properties that have not provided accurate surface area, are removed.

In LCA, the emissions are reported in stages starting from A1-A5 which consider the construction materials, their transportation and the construction process, B1-B7 which consider the use phase emissions including the replacement and refurbishment of the properties and C1-C4 which consider the deconstruction and end-of-life processes. Stage D presents the benefits from recycling of the construction materials.

The LCA results from the certified buildings will be expressed in per m² annual bases considering a service life of 60 years for the building. This will be averaged between the properties used. This will then be compared with a sample of 5 CSR reports that present the building emissions intensity similarly in a per m² annual bases. While this part cannot be used to put an actual representative number on the unreported emissions, it can give a ballpark figure that conveys the main point that the reporting extent does not give a representative picture of the real situation.

4 Results

4.1 Data from CSR reports

During the study, 215 companies were examined overall. To keep the results consistent and limit the study size, the list was narrowed down to 116 companies. First of all, hotel chains which have a slightly different business model but are still large investors in real estate were left out, second student housing companies were left out as these are not always purely profit driven but have other considerations in their operations. To limit the sample size further, UK was omitted completely as they have over 100 listed real estate companies. Table 1 below presents the summary of the results. Additional information can be seen from Appendix 1.

Table 1 Summary of analysed reports

| Country | Nr. of companies analyzed | Total value of portfolio (bn Eur) | Nr. of companies with CSR | % with CSR | Nr. of companies with certified buildings | % with certified buildings |
|-------------|---------------------------|-----------------------------------|---------------------------|------------|---|----------------------------|
| Austria | 7 | 16,993 | 3 | 43 % | 4 | 57 % |
| Belgium | 11 | 13,237 | 3 | 27 % | 5 | 45 % |
| Denmark | 2 | 0,62 | 0 | 0 % | 0 | 0 % |
| Finland | 4 | 10,6 | 3 | 75 % | 3 | 75 % |
| France | 20 | 91,377 | 10 | 50 % | 11 | 55 % |
| Germany | 18 | 68,79 | 9 | 50 % | 4 | 22 % |
| Greece | 3 | 2,32 | 1 | 33 % | 1 | 33 % |
| Italy | 4 | 5,41 | 2 | 50 % | 2 | 50 % |
| Netherlands | 5 | 45,392 | 2 | 40 % | 1 | 20 % |
| Norway | 2 | 2,75 | 2 | 100 % | 1 | 50 % |
| Poland | 2 | 1,682 | 0 | 0 % | 0 | 0 % |
| Ireland | 3 | 2,547 | 1 | 33 % | 1 | 33 % |
| Spain | 7 | 22,64 | 4 | 57 % | 4 | 57 % |
| Sweden | 13 | 49,516 | 8 | 62 % | 7 | 54 % |
| Switzerland | 6 | 22,111 | 4 | 67 % | 4 | 67 % |
| Turkey | 8 | 8,193 | 0 | 0 % | 0 | 0 % |

In 8 out of 16 countries reviewed, 50% or more of the companies had a dedicated CSR report or an integrated CSR section within the annual report that can be considered as extensive. In Denmark and Poland, none of the companies had such a report but also the sample size was small; 2 companies in each country. It is notable that, while Turkey has not yet joined the EU, from 8 companies that are listed property companies none had a CSR reporting in place.

There is a clear correlation between the companies with CSR reports and companies that own properties with green certificates. There are 10 companies that do have a CSR but do not mention if they do have buildings with green certificates, while 7 companies without a comprehensive CSR report had certified buildings in their portfolio. The most commonly used certificates were LEED and BREEAM, which is due to their application to international projects. In countries with well-established local certification systems, the local certificates

were as popular as the international ones. In France, many of the companies used HQE, while in Austria and Germany DGNB was a popular certification system. Similarly, in Sweden the local certification Miljöbyggnad was the most common one, as was Minergie certification system in Swiss.

From the 50 companies that did have a CSR report using some common framework, by far the most common framework for reporting GHG emissions was GRI G4 that was used by 38 of the companies analyzed. The second most popular guidelines for reporting was the EPRA sBPR that were used by 24 companies, many of them stating to follow both GRI and EPRA guidelines. Both the GRI G4 framework and EPRA sBPR are aligned with the GHG protocol scope approach and therefore are comparable to each other. Every single company that reported the amounts of their GHG emissions followed this approach and only 4 companies that did have a CSR report did not report their GHG emissions.

The importance of LCA approach for new developments was identified by 9 companies in their CSR reports. One company used ÖkoKauf Wien for all of the procurements, while one company had a commitment to reduce the GHG emissions from the new construction projects by 35%. A single company CeGEREAL reported the actual GHG emissions from categories not included in the GRI G4 scope including the construction materials used for new construction and renovations for that year using Bilan Carbone audit. Figure 5 shows the GHG emissions from CeGEREAL's 3 projects that include material emissions.

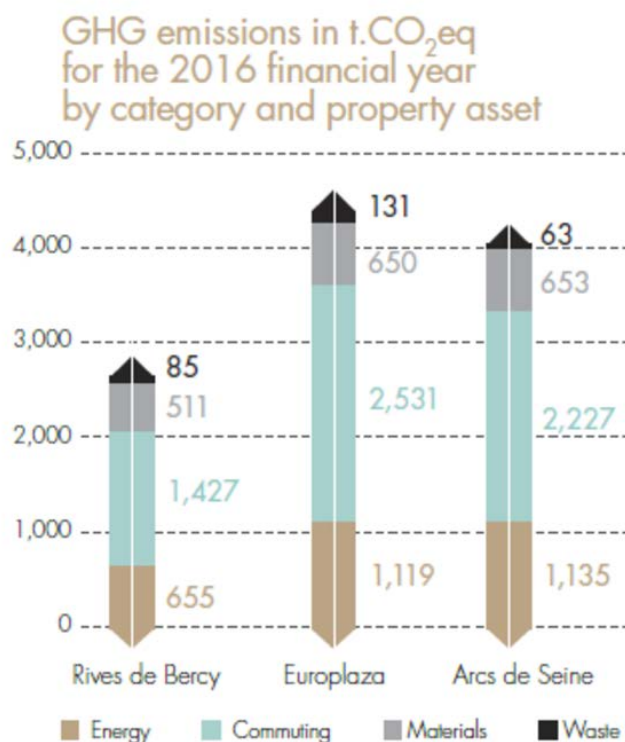


Figure 5 Emissions from 3 CeGEREAL properties for year 2016 (CeGEREAL, 2016)

4.2 Questionnaire

The questionnaire was answered by 41 participants. The job positions and companies from represented by the participants varied considerably. The sample consists of people in different parts of the value chain in the construction and real estate sector. There are architects and engineers that are involved in the early stages of a construction project, as well as project managers, consultants and company directors. The geographical representation of the participants is worldwide with majority operating in Europe. The full detailed answers can be seen in the Appendix 2.

Over 90% of the respondents have worked with green building certificates beforehand, LEED and BREEAM being again the most popular ones by far. On the average, 40% of the projects that the participants were involved used some green certification system. The number is this high as there were a number of respondents working particularly with the certifications. If we look at large engineering and construction companies (100+ projects each year) the number of certified projects vary between 1% and 25%. However, one respondent explicitly stated that in his opinion investors do not care about green certifications.

According to the questionnaire the LCA process is a fairly time consuming one: 43,5% respondents used between one and 4 weeks to perform LCA, while 13% spent more than a month. 26,1% of respondents were able to perform an LCA in less than a week. Detailed results can be seen below in Figure 6 and in Appendix 2.

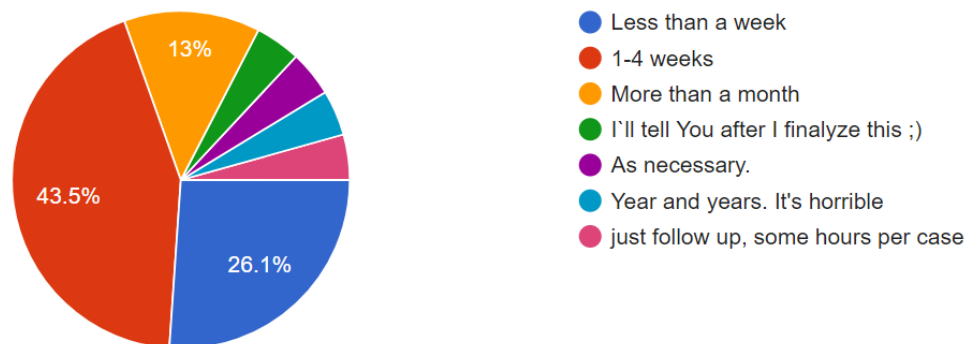


Figure 6 Time spent on an LCA

The biggest problems with LCA as identified by the respondents are: the tools for LCA are difficult to use, it takes too many working hours to do it and by far the most prevalent problem (96%) is the data availability or lack thereof. 11 respondents stated that they have not needed an LCA so far. Difficulty of LCA and lack of knowledge was identified as the biggest barriers for performing LCA, 3 and 4 respondents respectively.

The difficulty of performing an LCA is further emphasized in the fact that 77% of the respondents answered that they would do LCA if it would be easier. Despite the difficulties, 66% of respondents answered that they think that they will be performing an LCA within the next year. 86% of respondents answered that they would perform LCA if it would be better integrated with BIM.

According to the respondents, the clients are mostly interested in reducing investment costs (75%) followed by improving building quality (68%) and improving the image of the company (68%). Attracting investors and reducing the life-cycle cost of the buildings are the least important factors. On the other hand, the respondents found that LCA is the most helpful in reducing the environmental impacts of the project (17 respondents), evaluating different design options (16 respondents) and achieving credits towards green certification (15 respondents).

The satisfaction with the tools used for LCA is mediocre at 45% of respondents giving a score of 3 (1 – worst, 5 - best). Not a single respondent was fully happy with the tools that they use. The factors important in choosing a tool to perform LCA were the data availability, simplicity of use and price.

4.3 Certified building benchmark

Using One Click LCA web application, the emissions from LCA of BREEAM certified buildings was gathered. Only the GWP (kg of CO₂-eq) emissions of these buildings were considered. To create the benchmark, 16 office buildings and 10 retail buildings were used. The total emissions during the life-cycle of these buildings were divided with the gross floor area of the properties. From the 16 office buildings, there were 2 clear outliers that had the emissions multiple times lower than the average value and therefore were omitted from the benchmark. Similarly, in the retail sector, there were 3 outliers that were either unreasonably high or low. After removing the outliers, the average values for office buildings and retail buildings were calculated using assumed service life of 60 years.

| Company | Type | Country | Reported CO ₂ /m ² /a | Benchmark CO ₂ -eq/m ² /a | Reported/Benchmark |
|--------------------------------------|-----------------|-------------|---|---|--------------------|
| Kungsleden AB | Office | Sweden | 10 | 36 | 27 % |
| Hispania Activos Inmobiliarios, S.A. | Office | Spain | 13 | 36 | 37 % |
| CeGeREAL | Office | France | 24 | 36 | 68 % |
| Swiss Prime Site AG | Office + Retail | Swiss | 24 | 51 | 47 % |
| Klépierre | Retail | France | 20 | 66 | 30 % |
| Citycon | Retail | Finland | 46 | 66 | 70 % |
| Unibail-Rodamco SE | Retail | Netherlands | 16 | 66 | 24 % |
| Deutsche Wohnen AG | Residential | Germany | 23 | 36 | 64 % |

Figure 7 Reported emissions against the benchmark

The average emissions from the 16 office buildings were 36 kg of CO₂-eq per square meter per year, the figure for retail space was much higher at 66 kg of CO₂-eq per square meter per year. For mixed portfolios, the weighted average value was used.

From the real estate companies, that were analyzed before, eight were chosen to be compared to this benchmark. The companies selected were all large companies with portfolios of multiple billion Euros and all were investors that also develop new properties and have comprehensive CSR reporting. For these eight companies, the CO₂ emission intensity was collected from their CSR report. These eight companies follow the GRI G4 framework and report only the use phase emissions as per the guidelines.

If we compare the benchmarks which consider all the life-cycle stages of the building, including the construction phase and demolition, to the values reported by the real estate companies, it can be seen that all of the reported emissions are considerably lower than the LCA values. The reported emissions by the companies were between 24% and 68% of the emissions in the benchmark as seen in Figure 7. It must be noted that the LCA emissions are CO₂-eq which takes into account other GHG that are emitted during the life-cycle of the building and then equated to CO₂ emissions. The comparison between the benchmark and the reported emissions is not intended to be used as proof that the emissions reported are lower by a certain percentage. Rather it illustrates a point that by not considering the full LCA of the building the reported emissions have the potential to ignore a considerable part of the GHG emissions from buildings.

5 Conclusions and Discussion

The fact that global warming is one of the most pressing issues of our time has been documented extensively. The scientific community agrees, beyond a reasonable doubt, that the anthropogenic greenhouse gas emissions are a major cause of global warming. Therefore, initiatives to reduce the human caused emissions are becoming commonplace. Scientists agree that to avoid an irreversible and catastrophic climate change, the global warming needs to be kept below 2 degrees Celsius. To achieve this, the increase in GHG emissions from human activities needs to stop and be reversed.

European union countries have been one of the most forward-thinking countries in their efforts by introducing legislations and other initiatives to reduce the GHG emissions by 80% by year 2050 comparing to 1990. To achieve this, the EU has implemented a multifaceted approach with number of regulations that each play a significant role. The EU Emissions Trading system is the main tool to reduce the emissions from industries, such as heat and power generation, production of steel and other energy intensive materials and aviation among other. There is a directive for reduction of energy use in buildings and industry and another directive supporting the use of renewable energy sources. Both legislations approach the problem from different angle to achieve the same common goal.

Buildings in EU are responsible for 40% of primary energy consumption and 36% of total GHG emissions making it the highest single polluting industry in EU. At the same time, buildings represent the most cost-effective reductions that can considerably contribute to the EU's total GHG emission reduction goals. Recognizing the high emissions from the buildings, EU has implemented specific regulations towards buildings, specifically "Energy performance of buildings" and "Energy efficiency" directive. These directives, however, focus on the use phase of the buildings only.

Emissions from buildings are not limited to the use phase alone, but occur during the whole life-cycle of the building. Life-Cycle Assessment is a scientific method that is often used to assess the total impacts of a building. This method prevents the emissions shifting from one stage of the building's life-cycle to another and from one country or region to another. To account for emissions where the EU directives fall short, there are many green building certificates. The scope of these certifications differs significantly but many of them include emissions that go beyond the use phase of the building. Multiple studies suggest that there are benefits of green buildings that go beyond the environmental like economic and social ones.

All corporations have some impact on the environment. The awareness of these impacts has given rise to Corporate Sustainability Reporting (CSR). CSR is a way for companies to communicate about the risks and concerns that its stakeholders might have. Due to the significant GHG emissions that buildings produce, it should be just logical that all real estate companies report their emissions. To help companies report their emissions, there are multiple frameworks and guidelines that can be followed. The most popular framework is the GRI G4 which is also aligned with the GHG Protocol approach of reporting the emissions in 3 different scopes. These guidelines, however, apply only to the operational emissions of the buildings and therefore might ignore 50% of the total emissions from the building.

Traditionally, it has been commonly known in industries that 80% of the GHG emissions from buildings occur during the use phase and only 20% come from other building life-cycle stages. This ratio has been changing in recent years due to improvements in energy efficiency in buildings as well as decarbonization of energy mixes. For a new energy efficient building, using a lot of renewable energy, the use phase emissions are closer to 50-60%, making the other stages more important.

Beyond the economic, social and environmental benefits that green buildings have, there are both direct and indirect costs associated with GHG emissions. The expansion of EU ETS or introduction of a direct tax on CO₂ could pose risks to the real estate sector. In addition, there has been a movement towards divesting from heavy polluters in recent years that could mean higher scrutiny by investors towards GHG emissions. Of course, parallels cannot be drawn between coal mining and real estate, since we can exist without the former but not the latter one.

The first step towards reducing the emissions is proper accounting for them. As can be seen from the review of listed real estate companies in Europe, they fall short in reporting. From the reviewed 116 companies only less than half had a comprehensive CSR report. And even fewer companies accounted for their emissions with the current industry standard of reporting. There were companies that included some note about the sustainability but it often seemed very superficial. 9 companies stood out from the rest in the scope of their sustainability report by mentioning LCA or the emissions embodied in construction materials. A single company went as far as stating that it aims at reducing the emissions from new construction by 35%.

48 companies reported the use of green building certificates in new development projects or renovations. While not all certified buildings require an LCA, most likely a good portion of them have performed one. This means that the accounting for GHG emissions has been done but not reported. Due to the complexity of an LCA process this is not a straight forward task and requires industry guidelines. EU level common framework for core indicators for building environmental performance is largely based on the LCA and has the potential of closing the gap that exists between green building certificates and CSR reporting. However there needs to be a standardized way of how LCA results could be incorporated with the current reporting guidelines.

The survey shows that the industry experts are expecting the LCA to gain popularity, largely because of the green building certificate. It also identified that LCA is perceived as time consuming and difficult process. Once again, a development of common standards for performing an LCA and establishing large databases could solve this issue. There are now tools available that integrate the LCA process with Building Information Models (BIM) and other modelling software's. This has the potential to make the LCA process a seamless one.

Using the benchmark gathered from one such tool, it is clear, that the reporting of GHG emissions from real estate companies is incomplete. While, by no means, intended to definitively state what share of emissions is not reported, this comparison illustrates the issue. There is clearly a gap between the current reported emissions and actual emissions in the real estate industry. With LCA becoming more and more commonplace there needs to be a development in the industry towards full disclosure. If the emissions from full life-cycle

of the building are not reported then there is no way of measuring the performance or improvements regarding GHG emissions.

In summary, the GHG reporting in real estate currently is mediocre at best. Half of the companies do not report anything on their emissions and even fewer consider environmental aspects as a core concern. The laggards of the industry must catch up quickly, while the industry leaders must work towards better disclosure and transparency. A prudent investor will consider the environmental impacts of their investment as seen in recent years.

5.1 *Quality of Work and Further Studies*

The data collected during the research are in line with the scope that was defined in the beginning of it. Wherever data has high potential of error it is stated so in the text. The data was gathered from a long list of companies that use different reporting methods and therefore some assumptions were made while collecting the financial data. The most crucial data on the emissions follow a common framework and therefore, are reliable. Not all information was available in English that could lead to absence of some data despite the best efforts. For creating a benchmark for buildings with green certificates a relatively small sample was used due to lack of available data. For purposes of full transparency all of the limitations were stated where relevant.

Future research should focus on measuring the actual emissions from real estate companies that take part in project development. A large real estate company can sell and buy many assets per year and therefore it is not clear who's responsibility it is to report on embodied emissions as they occur only during certain period of the buildings life-cycle such as construction or demolishing. Different approaches to accountability in real estate should be examined to ensure full transparency. Furthermore, the potential for integrating LCA results into CSR reporting should be examined in order to develop industry wide guidelines. In many cases the emissions data is available but not reported due to lack of guidelines. There is no real incentive to report more than required because companies that follow the current guidelines are already seen as environmentally more conscious.

References

- Anderson J. (2011) Carbon leader briefings - Materials, products and carbon. [pdf] PE International. Available at: <https://www.scribd.com/document/309873189/Materials-Products-and-Carbon-Briefing> [Accessed 2.8.2017]
- Arrhenius, S. (1896) On the influence of carbonic acid in the air upon the temperature of the ground. Phil. Mag. Ser. 5, 41, 237–276 (1896). Available at: http://www.rsc.org/images/Arrhenius1896_tcm18-173546.pdf [Accessed 4.8.2017]
- Artola, I.; Rademaekers, T. K.; Williams, T. R.; Yearwood, T. J. (2016) Boosting Building Renovation: What potential and value for Europe? [pdf] Available at: [http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU\(2016\)587326_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU(2016)587326_EN.pdf) [Accessed 4.8.2017]
- ARUP. (2015) Green Construction Board Loe Carbon Routemap for the Built Environment – 2015 Routemap Progress, Technical Report. [pdf] Available at: <http://www.greenconstructionboard.org/otherdocs/2015%20Built%20environment%20low%20carbon%20routemap%20progress%20report%202015-12-15.pdf> [Accessed 25.8.2017]
- Ballou, B.; Heitger, D. (2005) The Rise of Corporate Sustainability Reporting: A Rapidly-Growing Assurance Opportunity. Richard T. Farmer School of Business Miami University. [pdf] Available at: <http://www.sba.muohio.edu/balloubj/images/Ballou%20Heitger%20CSR%2024Jul05.pdf> [Accessed 9.8.2017]
- Basbagill, F. Flager, M. Lepech, M. Fischer, Application of life-cycle assessment to early stage building design for reduced embodied environmental impacts, Build. Environ. 60(2013)81–92. Available at: <http://www.sciencedirect.com/science/article/pii/S0360132312003071> [Accessed 4.8.2017]
- Bergsdal, H., Strömann, A. H., & Hertwich, E. G. (2004). The Aluminium Industry – Environment, Technology and Production. NTNU Program for industriell økologi Raport. No.: 8/2004.
- BIORES. (2011) Understanding Carbon Leakage: Developing Country Trade Vulnerabilities to EU Climate Policies. BIoRES, Vol. 5, No. 4. [online] Available at: <https://www.ictsd.org/bridges-news/biores/news/understanding-carbon-leakage-developing-country-trade-vulnerabilities-to-eu> [Accessed 4.8.2017]
- BIS (2010) ESTIMATING THE AMOUNT OF CO₂ EMISSIONS THAT THE CONSTRUCTION INDUSTRY CAN INFLUENCE . [rep.] ESTIMATING THE AMOUNT OF CO₂ EMISSIONS THAT THE CONSTRUCTION INDUSTRY CAN INFLUENCE . Department for Business, Innovation and Skills. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31737/10-1316-estimating-co2-emissions-supporting-low-carbon-igt-report.pdf [Accessed 15.7.2017]

Brown, H.S., de Jong, M., Levy, D.L., 2009. Building institutions based on information disclosure: lessons from GRI's sustainability reporting. *Journal of Cleaner Production* 17, pp 571–580.

Burke, M.; Solomon, M.; Miguel, E. (2015) Global Non-linear Effect of Temperature on Economic Production. *Nature*, Vol. 527, Issue 7577, pp. 235-239. doi:10.1038/nature15725

Buyle, M.; Braet, J.; Audenaert, A. (2013) Life Cycle Assessment in the Construction Sector: A Review. *Renewable and Sustainable Energy Reviews*, Vol. 26, pp. 379-388. <https://doi.org/10.1016/j.rser.2013.05.001>

Bülent Ünalın, Alberto Celani, Harun Tanrıvermiş, Mehmet Bülbül and Andrea Ciaramella (2014) IMPACT OF EMBODIED CARBON IN THE LIFE CYCLE OF BUILDINGS ON CLIMATE CHANGE FOR A SUSTAINABLE FUTURE. [pdf] Sustainable Housing Construction. Available at: https://www.academia.edu/10085007/IMPACT_OF_EMBODIED_CARBON_IN_THE_LIFE_CYCLE_OF_BUILDINGS_ON_CLIMATE_CHANGE_FOR_A_SUSTAINABLE_FUTURE?auto=download [Accessed 2.8.2017]

Carrington, D. (2016) Fossil Fuel Divestment Funds Double to \$5tn in a Year. *The Guardian*. [online] Available at: <https://www.theguardian.com/environment/2016/dec/12/fossil-fuel-divestment-funds-double-5tn-in-a-year> [Accessed 12.8.2017]

CeGeReal. (2016) Smart Places for Business – Annual Report. [pdf] CeGeReal. Available at: http://corp.cegereal.com/sites/default/files/ra/cegereal_ra_2016_gb_bd_0.pdf [Accessed 15.8.2017]

Center for Climate and Energy Solutions. (2015) OUTCOMES OF THE U.N. CLIMATE CHANGE CONFERENCE IN PARIS [pdf] C2ES. Available at: <https://www.c2es.org/international/negotiations/cop21-paris/summary> [Accessed 15.9.2017]

Chegut, A.; Eichholtz, P.; Kok, N. (2013) Supply, Demand and the Value of Green Buildings. *Urban Studies* 1-22. [online] Available at: http://www.corporate-engagement.com/files/file/CEK_US_2013.pdf [Accessed 3.8.2017]

Cubi, E.; Bergerson, J. (2014) Should Building Energy Simulation Tools Integrate Life Cycle Assessment? A Discussion of the Potential Benefits and Challenges. [pdf] University of Calgary, Alberta, Canada. Available at: <http://www.ibpsa.org/proceedings/eSimPapers/2014/8A.6.pdf> [Accessed 25.8.2017]

D'Agostino, D.; Zangheri, P.; Castellazzi, L.; (2016) Towards Nearly Zero Energy Buildings in Europe: A Focus on Retrofit in Non-Residential Buildings [pdf] Available at: <http://www.mdpi.com/1996-1073/10/1/117/pdf> [Accessed 18.8.2017]

Deloitte (2014) Investments With Social Impacts Leading the Way. [pdf] Available at: <https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/gx-grl4-impact-investing.pdf> [Accessed 20.9.2017]

Deutsche Bank Research. (2010) Green Buildings – A Niche Becomes Mainstream. [pdf] Deutsche Bank Research. Available at: https://sallan.org/pdf-docs/DB_2010_Green%20Buildings.pdf [Accessed 18.8.2017]

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings

Dodd, N.; Donatello, S.; Gama-Caldas, M.; Van de Vyver, I.; Debacker, W.; Stranger, M.; Spirinckx, C.; Dugrosprez, O.; Allacker, K.; (2016) Guide to the consultation: 'Draft common EU framework of core indicators for the environmental performance of EU buildings'. [pdf] Available at: https://www.google.fi/url?sa=t&ret=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjBp8WF-ePWAhUpOpoKHQOGA70QFggkMAA&url=http%3A%2F%2Fsusproc.jrc.ec.europa.eu%2FEfficient_Buildings%2Fdocs%2FREB_Consultation_guide.pdf&usg=AOvVaw38JUUPq7zsb64XIjzfeCbP [[Accessed 10.8.2017]]

Doman, L. (2016) U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. [online] Available at: <https://www.eia.gov/todayinenergy/detail.php?id=26212> [Accessed 31.7.2017]

Ebert, T.; Eßig, N.; Hauser, G. (2011) Green Building Certification Systems: Assessing Sustainability, International System Comparison, Economic Impact of Certification. Edition Detail Green Books. Available through Google Books: https://books.google.fi/books?id=pYzTAAAAQBAJ&pg=PA142&lpg=PA142&dq=green+building+certificates+not+used+in+CSR&source=bl&ots=A2Ttxa_BDi&sig=R-H7nZHMVo5aCs0Y7sA6tElcRQk&hl=en&sa=X&ved=0ahUKEwj33LfDgdrWAhXnNJoKHbsOAfAQ6AEIPzAE#v=onepage&q&f=false [Accessed 29.8.2017]

Eccles, R.; Krzus, M.; Rogers, J.; Serafeim, G. (2012) The Need for Sector-Specific Materiality and Sustainability Reporting Standards. Journal of Applied Corporate Finance, Vol. 24, No. 2, pp. 8-14. [online] Available at: <http://www.sasb.org/wp-content/uploads/2012/06/JACF-Sector-Materiality.pdf> [Accessed 4.8.2017]

EIA (2016) U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. [online] International Energy Outlook 2016-Buildings sector energy consumption - Energy Information Administration. Available at: <https://www.eia.gov/outlooks/ieo/buildings.php> [Accessed 10.7.2017]

European Environment Agency. (2008) Climate change targets: 350 ppm and the EU two-degree target. [pdf] European Environment Agency. Available at: <https://www.eea.europa.eu/highlights/climate-change-targets-350-ppm-and-the-eu-2-degree-target> [Accessed 15.7.2017]

European Environment Agency. (2015) Trends and Projections in Europe 2015 – Tracking Progress Towards Europe's Climate and Energy Targets. [pdf] European Environment Agency. Available at: <https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2015> [Accessed 23.8.2017]

EPRA. (2017) About. [online] Available at: <http://www.epra.com/about-us> [Accessed 6.8.2017]

EPRA, 2014. EPRA Sustainability BPR 2014. European Platform of regulatory authorities http://www.epra.com/media/EPRA_Sus-BPR_2014_1424420907752.pdf [Accessed 6.8.2017]

European Commission. (2016) EU REFERENCE SCENARIO 2016 ENERGY, TRANSPORT AND GHG EMISSIONS TRENDS TO 2050. [rep.] EU REFERENCE SCENARIO 2016 ENERGY, TRANSPORT AND GHG EMISSIONS TRENDS TO 2050. EUROPEAN COMMISSION. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf [Accessed 29.7.2017]

European Commission. (2017a) Buildings. [online] Available at: <https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings> [Accessed 19.8.2017]

European Commission. (2017b) EU Building Stock Observatory. [online] Available at: <https://ec.europa.eu/energy/en/eubuildings> [Accessed 19.8.2017]

European Commission. (2017c) The Industrial Emissions Directive – Summary of Directive 2010/75/EU on industrial emissions. [online] Available at: <http://ec.europa.eu/environment/industry/stationary/ied/legislation.htm> [Accessed 25.8.2017]

European Commission. (2017c) The EU Emissions Trading System. [online] Available at: https://ec.europa.eu/clima/policies/ets_en [Accessed 28.8.2017]

European Parliament. (2016) Boosting Building Renovation: What Potential and Value for Europe? Study for the ITRE Committee. [pdf] European Parliament. Available at: [http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU\(2016\)587326_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU(2016)587326_EN.pdf) [Accessed 5.8.2017]

Eurostat (2017) Extra-EU trade in manufactured goods. [online] Extra-EU trade in manufactured goods - Statistics Explained. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Extra-EU_trade_in_manufactured_goods [Accessed 31.7.2017].

Floyd, J.; Fowler, Jr. (2013) Survey Research Methods. 5th Edition. SAGE Publications. ISBN-1483323595

France-Presse, A. (2016) Norway's Oil-Based Wealth Fund Sells Out of More Fossil Fuel Companies. The Guardian. [online] Available at: <https://www.theguardian.com/environment/2016/feb/05/norways-wealth-fund-sells-out-of-73-companies-as-fossil-fears-grow> [Accessed 4.8.2017]

Fuerst, F.; McAllister, P. (2011) Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values. Journal of Real Estate Economics, Vol. 39,

pp. 45-69. [online] Available at: <http://immobilierdurable.eu/medias/sites/5/2014/09/Fuerst-article-autorisé.pdf> [Accessed 15.8.2017]

G4 Online. (2017) Materiality. [online] Available at: <https://g4.globalreporting.org/how-you-should-report/reporting-principles/principles-for-defining-report-content/materiality/Pages/default.aspx> [Accessed 14.8.2017]

Geller, H.; Harrington, P.; Rosenfield, A.; Tanishima, S.; Unander, F. (2006) Policies for Increasing Energy Efficiency: Thirty Years of Experience in OECD Countries. Energy Policy, Vol. 34, Issue 5, pp. 556-573. <https://doi.org/10.1016/j.enpol.2005.11.010>

Global Reporting Initiative. (2008) A Snapshot of Sustainability Reporting in the Construction and Real Estate Sector. [pdf] Global Reporting Initiative. Available at: <https://www.globalreporting.org/resource/library/A-Snapshot-of-sustainability-reporting-in-the-Construction-Real-Estate-Sector.pdf> [Accessed 8.8.2017]

Global Reporting Initiative. (2015) G4 Sustainability Reporting Guidelines: Reporting Principles and Standard Disclosures. [pdf] Global Reporting Initiative. Available at: <https://www.globalreporting.org/resource/library/GRIG4-Part1-Reporting-Principles-and-Standard-Disclosures.pdf> [Accessed 12.8.2017]

GRESB. (2017) 2017 Reference Guide. [online] Available at: <https://www.gresb.com/sites/default/files/2017-GRESB-RE-Reference-Guide.pdf> [Accessed 2.8.2017]

Grimmon, C. (2007) Urbanization and Global Environmental Change: Local Effects of Urban Warming. The Geographical Journal, Vol. 173, pp. 83-88. DOI: 10.1111/j.1475-4959.2007.232_3.x.

Gutro R. (2005) NASA - What's the Difference Between Weather and Climate? [online] Available at: https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

Gunther, M. (2015) Sustainable Investing: Are Companies Finally Moving Money Away From Fossil Fuels? The Guardian. [online] Available at: <https://www.theguardian.com/sustainable-business/2015/sep/16/goldman-sachs-morgan-stanley-merrill-lynch-fossil-fuel-divestment> [Accessed 7.8.2017]

Hale, T.; Held, D. (2011) Handbook of Transnational Governance: Institutions & Innovations. [e-book] Polity Press. Available through Google Books website: https://books.google.fi/books?hl=en&lr=&id=SkOq6n83BMcC&oi=fnd&pg=PA281&dq=global+reporting+initiative&ots=1d7G2rv1pg&sig=VtvG56mTw9tXfeZBPH2E_YYmzfY&redir_esc=y#v=onepage&q=global%20reporting%20initiative&f=false [Accessed 20.8.2017]

Hammond, G.; Jones, C. (2008) Embodied Energy and Carbon in Construction Materials. Institution of Civil Engineers, Energy 161, Issue EN2, pp. 87-98. [online] Available at: [http://opus.bath.ac.uk/12382/1/Hammond_%26_Jones_Embodied_energy_%26_carbon_Pr oc ICE-Energy_2008_161\(2\)_87-98.pdf](http://opus.bath.ac.uk/12382/1/Hammond_%26_Jones_Embodied_energy_%26_carbon_Pr oc ICE-Energy_2008_161(2)_87-98.pdf) [Accessed 18.8.2017]

Herczeg. (2014) Resource Efficiency in the Building Sector, Final Report. [pdf] Ecorys. Available at: <http://ec.europa.eu/environment/eussd/pdf/Resource%20efficiency%20in%20the%20building%20sector.pdf> [Accessed 22.8.2017]

HM Government. (2010) Low Carbon Construction, Innovation & Growth Team. [pdf] Department for Business, Innovation and Skills. Available at: <https://www.google.fi/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjghPzZ7eHWAhVhM5oKHemZD3YQFggkMAA&url=http%3A%2F%2Fwww.carbonaction2050.com%2Fsites%2Fcarbonaction2050.com%2Ffiles%2Fdocument-attachment%2FIGT%2520Low%2520Carbon%2520Construction.pdf&usg=AOvVaw3AoCOipPuiehHIDIXQQ-Ck> [Accessed 2.8.2017]

Howley, M.; Holland, M.; Dineen, D.; (2015) Energy in Ireland, Key Statistics [pdf] Available at: <https://www.google.fi/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiKh9OaheTWAhWhNpoKHxqRAYMQFggkMAA&url=http%3A%2F%2Fwww.seai.ie%2Fresources%2Fpublications%2FEnergy-in-Ireland-1990-2015.pdf&usg=AOvVaw1j-7V8QnRNYcGs6dYJgBSn> [Accessed 9.9.2017]

ICAP. (2015) Emissions Trading Worldwide – International Carbon Action Partnership (ICAP) Status Report 2015. [pdf] ICAP. Available at: https://icapcarbonaction.com/images/StatusReport2015/ICAP_Report_2015_02_10_online_version.pdf [Accessed 15.8.2017]

IEA. (2013) Transition to Sustainable Buildings – Strategies and Opportunities to 2050. [pdf] IEA. Available at: http://www.iea.org/publications/freepublications/publication/Building2013_free.pdf [Accessed 21.8.2017]

IEA PUBLICATIONS, 9 rue de la Fédération, 75739 PARIS CEDEX 15 Printed in France by International Energy Agency, June 2013
(IPCC, 2017b) http://www.ipcc.ch/news_and_events/docs/factsheets/FS_what_ipcc.pdf

IPCC. (2005) Carbon Dioxide Capture and Storage. [pdf] Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf [Accessed 17.8.2017]

IPCC. (2014a) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland, 151 pp. [online] Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf [Accessed 25.8.2017]

IPCC (2014b) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S.

Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2007) 1 Observed changes in climate and their effects. [online] AR4 SYR Synthesis Report - 1 Observed changes in climate and their effects. Available at: https://www.ipcc.ch/publications_and_data/ar4/syr/en/mains1.html [Accessed 31.7.2017]

Ioannou, I.; Serafeim, G. (2017) The Consequences of Mandatory Corporate Sustainability Reporting. Working Paper 11-100, Harvard Business School. [online] Available at: http://www.hbs.edu/faculty/Publication%20Files/11-100_ed78b358-dddd-41f0-9a05-5c1b430b15f9.pdf [Accessed 6.8.2017]

JLL. (2016) Taking Real Estate Transparency to the Next Level. Global Real Estate Transparency Index, 2016. [pdf] Available at: <http://www.jll.com/Research/Global-Real-Estate-Transparency-Index-2016.pdf> [Accessed 12.8.2017]

Jian Zuo and Zhen-Yu Zhao, (2014), Green building research—current status and future agenda: A review, Renewable and Sustainable Energy Reviews, 30, (C), 271-281

Kats, G. (2003) Green Building Costs and Financial Benefits. [pdf] Massachusetts Technology Collaborative. Available at: <http://staging.community-wealth.org/sites/clone.community-wealth.org/files/downloads/paper-kats.pdf> [Accessed 18.8.2017]

Klare, M. T. (2014) Europe's resource dilemma: Escaping the dependency trap. [online] Europe's World. Available at: <http://europesworld.org/2014/03/21/europes-resource-dilemma-escaping-the-dependency-trap/#.WX92BoiGOyw> [Accessed 31.7.2017].

LEED. (2013) Whole building life cycle assessment. [online] Available at: <https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthcar-9> [Accessed 2.8.2017]

Levine, M. D., Ürge-Vorsatz, D. Harvey, L. D. Mirasgedi, S. (2007) “Mitigating CO2 Emissions from Energy Use in the World's Buildings” Building Research and Information, vol. 35(4), pp. 379-398.

Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Lind, A.; Espergren, K.; Rosenberg, E.; Seljom, P, Fidje, A.; Lindberg, K. (2013) Analysis of the EU Renewable Energy Directive by a Techno-Economic Optimisation Model. Energy Policy, Vol. 60, No. 364. DOI: 10.1016/j.enpol.2013.05.053

Malik, A 2008, Causes of Climate Change (1), Rajat Publications, Delhi, IN. Available from: ProQuest ebrary. [6.8.2017]

McAlinden. (2015) Embodied Energy and Carbon. ICE. [online] Available at: <https://www.ice.org.uk/knowledge-and-resources/briefing-sheet/embodied-energy-and-carbon> [Accessed 23.8.2017]

Mulder, K.; (2006) Sustainable Development for Engineers. Greenleaf Publishing, ISBN 1874719195, 9781874719199

Mooney, A. (2017) Growing number of pension funds divest from fossil fuels, [online] Available at: <https://www.ft.com/content/fe88b788-29ad-11e7-9ec8-168383da43b7> [Accessed 27.8.2017]

Mozingo, L.; Arens, E. (2014) Quantifying the Comprehensive Greenhouse Gas Co-Benefits of Green Buildings. UC Berkeley: Center for the Built Environment. [online] Available at: <http://escholarship.org/uc/item/935461rm#> [Accessed 24.8.2017]

OECD. (2015) Carbon Dioxide Emissions Embodied in International Trade. OECD. [online] Available at: <http://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm> [Accessed 19.8.2017]

Östlund, U.; Kidd, L.; Wengström, Y.; Rowa-Dewar, N. (2011) Combining Qualitative and Quantitative Research Within Mixed Methods Research Designs: A Methodological Review. International Journal of Nursing Studies, Vol. 48, pp. 369-383. [online] Available at: https://repository.edulll.gr/edulll/bitstream/10795/2235/2/2235_2%20%20QUANTITY%20QUALITY.pdf [Accessed 10.8.2017]

Pérez-Lombard, L.; Ortiz, J.; Pout, C. (2008) A Review on Buildings Energy Consumption Information. Energy and Buildings, Vol. 40, pp- 394-398. [online] Available at: http://www.esi2.us.es/~jfc/Descargas/ARTICULOS/PAPER_LPL_1_OFF-PRINT.pdf [Accessed 28.8.2017]

Petersa, G.P., Minx, J.C. and and, C.L.W. (2011) Glen P. Peters. [online] Proceedings of the National Academy of Sciences. Available at: <http://www.pnas.org/content/108/21/8903.full> [Accessed 31.7.2017].

Rashid, A.; Yusoff, S. (2015) A Review of Life Cycle Assessment Method for Building Industry. Renewable and Sustainable Energy Reviews, Vol. 45, pp. 244-248. <https://doi.org/10.1016/j.rser.2015.01.043>

Regional REIT Limited. (2015) Report and Accounts 2015. [pdf] Regional REIT Limited. Available at: <http://www.regionalreit.com/~media/Files/R/Regional-Reit/investor-docs/results-and-presentations/FY%202015%20Annual%20Report.pdf> [Accessed 3.8.2017]

RICS. (2008) Breaking the Vicious Circle of Blame – Making the Business Case for Sustainable Buildings. [online] Available at: http://lorenz-immobilien.net/documents/RICS_FiBRE_Breaking_the_Vicious_Circle.pdf

Rudler, L.; McLean, M.; Bunzl, M. (2013) When Truth is Personally Inconvenient, Attitudes Change: The Impact of Extreme Weather on Implicit Support for Green Politicians and Explicit Climate-Change Beliefs. Psychological Science, Vol. 24, No. 11, pp. 2290-2296. [online] Available at:

https://www.researchgate.net/profile/Laurie_Rudman/publication/256931738_When_Truth_Is_Personally_Inconvenient_Attitudes_Change/links/0deec5324ae22ce139000000/When-Truth-Is-Personally-Inconvenient-Attitudes-Change.pdf [Accessed 25.8.2017]

S&P Global Market Intelligence. (2016) SNL Real Estate Global Coverage List May 2016. [pdf] S&P Global Market intelligence. Available at: <https://marketintelligence.spglobal.com/client-solutions/users/RE%20Coverage%20List%202016.pdf> [Accessed 13.8.2017]

Santamouris, M. (2014) On the Energy Impact of Urban Heat Island and Global Warming on Buildings. Energy and Buildings, Vol. 82, pp. 100-113. <https://doi.org/10.1016/j.enbuild.2014.07.022>

ScienceDaily. (2017) 'Heat Island' Effect Could Double Climate Change Costs for World's Cities. Science Daily. [online] Available at: <https://www.sciencedaily.com/releases/2017/05/170529133714.htm> [Accessed 19.8.2017]

Stephens, J. C. (2014), Time to stop investing in carbon capture and storage and reduce government subsidies of fossil-fuels. WIREs Clim Change, Vol. 5, pp. 169–173. doi:10.1002/wcc.266

Stewart, D.; Stewart, M.; Kamins, A. (1993) Secondary Research: Information Sources and Methods. Second Edition. [e-book] SAGE Publications. Available through Google Books website: https://books.google.fi/books?hl=en&lr=&id=Oe3MrNsOjkkC&oi=fnd&pg=PP11&dq=secondary+research+methods&ots=D0T_oI4iEd&sig=P4jWbbvMCbj39WC5Id2HhI9WIKI&redir_esc=y#v=onepage&q=secondary%20research%20methods&f=false [Accessed 20.8.2017]

Swartz, J. (2016) China's National Emissions Trading System. [pdf] International Centre for Trade and Sustainable Development. Available at: https://www.ictsd.org/sites/default/files/research/Chinas_National_ETS_Implications_for_Carbon_Markets_and_Trade_ICTSD_March2016_Jeff_Swartz.pdf [Accessed 19.8.2017]

Säynäjoki, A.; Heinonen, J.; Junnila, S.; Horvath, A. (2017) Can Life-cycle Assessment Produce Reliable Policy Guidelines in the Building Sector? Environmental Research Letters, Vol. 12, No. 1. [online] Available at: <http://iopscience.iop.org/article/10.1088/1748-9326/aa54ee/pdf> [Accessed 20.8.2017]

UNEP. (2009) Buildings and Climate Change [pdf] Available at: http://www.greeningtheblue.org/sites/default/files/Buildings%20and%20climate%20change_0.pdf [Accessed 3.8.2017]

UNFCCC, (2011) Fact sheet: Climate change science - the status of climate change science today . [publication] Fact sheet: Climate change science - the status of climate change science today . UNFCCC. Available at: https://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_science.pdf [Accessed 25.7.2017]

United Nations. (2015) Paris Agreement. [online] Available at: http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf [Accessed 3.8.2017]

Vaughan, A. (2015) Church of England Ends Investments in Heavily Polluting Fossil Fuels. The Guardian. [online] Available at: <https://www.theguardian.com/environment/2015/apr/30/church-of-england-ends-investments-in-heavily-polluting-fossil-fuels> [Accessed 8.8.2017]

Vierra, S. (2016) Green Building Standards and Certification Systems. Whole Building Design Guide. [online] Available at: <https://www.wbdg.org/resources/green-building-standards-and-certification-systems> [Accessed 13.8.2017]

World Business Council for Sustainable Development. (2016) The Business Case for the Use of Life Cycle Metrics in Construction & Real Estate. [pdf] WBCSD Material. Available online: <http://www.wbcsd.org/contentwbc/download/1930/24581> [Accessed 9.8.2017]

Weisbach, D. (2011) Carbon Taxation in Europe: Expanding the Eu Carbon Price. University of Chicago Law & Economics, Olin Working Paper No. 566. <http://dx.doi.org/10.2139/ssrn.1898798>

Wensen, K.; Broer, W.; Klein, J.; Knopf, J, (2011) The State Of Play In Sustainability Reporting In The European Union. [pdf] Available at: <http://ec.europa.eu/social/BlobServlet?docId=6727&langId=en> [Accessed 14.8.2017]

World Green Building Council. (2016) EU Unveils New Green Building Policy Objectives. [online] World Green Building Council. Available at: <http://www.worldgbc.org/news-media/eu-unveils-new-green-building-policy-objectives> [Accessed 13.8.2017]

List of Appendices

Appendix 1. Data collected from annual sustainability reports

Appendix 2. Answers of the internet survey

Appendix 3. Benchmark of GHG emissions from building LCA

Appendix 1. Data collected from annual sustainability reports

| Name of the company | Portfolio value | Floor area | Sustainability reporting | Framework used | GHG Tons of CO2 | Certificates |
|--------------------------------------|-----------------|------------|--------------------------|----------------|-----------------|--------------------------|
| | | | | | | |
| Austria | | | | | | |
| Atrium European Real Estate Limited | 2,6bn | 1,1m | Y | EPRA | 157,914 | 3 BREEAM |
| CA Immobilien Anlagen AG | 3,8bn | 1,3m | Y | GRI | 91,478 | 60% DGNB, LEED, BREEAM |
| Conwert Immobilien Invest SE | 2,8bn | 2,04m | Y | EPRA | 35,437 | - |
| IMMOFINANZ Group | 4bn | 1,7m | N | - | - | - |
| S IMMO AG | 2,1bn | 1,3m | N | - | - | - |
| UBM Realitätenentwicklung AG | 1,35bn | - | N | - | - | Owns certified buildings |
| Warimpex Finanz- und Beteiligungs AG | 343m | - | N | - | - | 1 BREEAM |
| | | | | | | |
| Belgium | | | | | | |
| Aedifica SA | 1,46bn | - | N | - | - | - |
| Banimmo | 350m | - | N | - | - | - |
| Befimmo SA | 2,5bn | 850k | Y | EPRA | 337 | BREEAM in use |
| Cofinimmo SA | 3,4bn | 1,78m | Y | EPRA | 115,456 | 2 BREEAM |
| Intervest Offices & Warehouses | 632m | 743k | N | - | - | - |
| Leasinvest Real Estate SCA | 860m | 450k | N | - | - | 1 BREEAM |
| Retail Estates N.V. | | | | | | |
| Vastned Retail Belgium SA | 358m | 90k | N | - | - | - |
| VGP NV | 681k | 416k | N | - | - | - |
| Warehouses De Pauw | 2,2bn | 3,38m | Y | EPRA | 4,258 | 3 BREEAM |
| Wereldhave Belgium | 775m | - | N | - | - | 1 BREEAM |
| | | | | | | |
| Denmark | | | | | | |
| Nordicom A/S | | | | | | |
| TK Development A/S | | | | | | |
| | | | | | | |
| Finland | | | | | | |
| Citycon Oyj | 5bn | - | Y | GRI G4 | 60,295 | 2 LEED |

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| | | | | | | |
|--|--------|------|---|---------------------|--------|-------------------|
| Orava Residential Real Estate Investment Trust Plc | 207m | 107k | N | - | - | - |
| Sponda Plc | 3,8bn | 1,2m | Y | GRI G4, EPRA | 55,299 | 7 BREEAM, LEED |
| Technopolis Plc | 1,6bn | 746k | Y | GRI G4, EPRA | 33,008 | 25 LEED |
| | | | | | | |
| France | | | | | | |
| Acanthe Développement | 181m | 17k | N | - | - | - |
| AccorHotels | | | | | | |
| Affine | 537m | 346k | N | - | - | - |
| Altarea Cogedim | 2,7bn | 700k | N | - | - | HQE, BREEAM |
| ANF Immobilier | 49m | 401k | Y | EPRA, GRI CRESS | 4,462 | HQE, BREEAM |
| CeGeREAL | 1,14bn | 150k | Y | GRI G4, EPRA | 11,600 | - |
| Eurosic | 7,7bn | 1,7m | N | - | - | HQE |
| Foncière des Murs | | | | | | |
| Foncière des Régions | 19bn | 797k | Y | GRI G4 | 30,160 | HQE, BREEAM, LEED |
| Foncière Développement Logements | | | | | | |
| Gecina | 13,3bn | 1m | Y | GRI G4 | 35,000 | HQE |
| Icade | 9,7bn | - | Y | GRI G4, EPRA | 22,127 | BREEAM, HQE |
| Klépierre | 22,8bn | 4,3m | Y | GRI G4 | 75,364 | BREEAM |
| Les Nouveaux Constructeurs | | | | | | |
| Mercialys | 3,7bn | 875k | N | EPRA, GRESB | 12,000 | BREEAM |
| Nexity | | | | | | |
| Orco Property Group S.A. | 491m | - | - | - | - | - |
| Société de la Tour Eiffel | 1,14bn | 487m | Y | GRI G4, GRESB, EPRA | - | HQE |
| Société Foncière Lyonnaise | 5,7bn | - | Y | GRI G4, EPRA | 5,680 | HQE, BREEAM, LEED |
| TERREIS | 1,9bn | 170k | N | - | - | - |

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| | | | | | | |
|---|--------|-------|---|--------------|---------|-------------------|
| Züblin Immobilière France SA | 275m | - | N | - | - | HQE, BREEAM, LEED |
| | | | | | | |
| Germany | | | | | | |
| Accentro Real Estate AG | 260m | - | N | - | - | - |
| Adler Real Estate AG | 1bn | - | N | - | - | - |
| ADO Properties S.A. | 1,6bn | - | N | - | - | - |
| alstria office REIT-AG | 3bn | 1,5m | Y | GRI G4, EPRA | 130,000 | 8 DGNB |
| BUWOG AG | 2b | 3,5m | Y | GRI G4 | 22,600 | - |
| DEMIRE Deutsche Mittelstand Real Estate AG | 272m | 1,1m | N | - | - | - |
| Deutsche EuroShop AG | 2,3b | 1m | Y | EPRA | 32,000 | |
| Deutsche Wohnen AG | 10bn | 9,5m | Y | GRI G4, EPRA | 147,000 | DGNB |
| DIC Asset AG | 3,4bn | 1m | Y | GRI G4, EPRA | 62,200 | - |
| Fair Value REIT-AG | 289m | 250k | N | - | - | - |
| Grand City Properties S.A. | 2,5b | 5,3m | Y | EPRA | 36,200 | - |
| Hamborner REIT AG HAB | 564m | | Y | GRI G4, EPRA | 11,800 | DGNB, LEED |
| IFM Immobilien AG | | 47k | N | - | - | - |
| PATRIZIA Immobilien AG | 19bn | | N | - | - | - |
| TAG Immobilien AG | 3,9bn | 4,8m | N | - | - | - |
| TLG IMMOBILIEN AG | 1,24bn | 1,42m | Y | GRI G4, EPRA | 10,000 | - |
| VIB Vermögen AG | 470m | 1m | N | - | - | - |
| Vonovia SE | 17bn | 20m | Y | GRI G4 | 16,000 | - |
| | | | | | | |
| Greece | | | | | | |
| Babis Vovos International Construction S.A. | 936m | - | - | - | - | - |
| Grivalia Properties REIC | 870m | 771m | Y | EPRA | 62,000 | 5 BREEAM, LEED |
| LAMDA Development S.A. | 508m | 147k | N | - | - | - |
| | | | | | | |
| Italy | | | | | | |
| Aedes SpA AE | 306m | | N | - | - | - |
| Beni Stabili SpA SIIQ | 4bn | | Y | GRI G4, EPRA | 1,999 | LEED, BREEAM |

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| | | | | | | |
|---------------------------------------|---------|-------|---|--------------|--------|---------------------|
| Immobiliare Grande Distribuzione SIIQ | 1,1bn | | Y | GRI G4, EPRA | 23,680 | BREEAM |
| Risanamento SpA | | | | | | |
| | | | | | | |
| Netherlands | | | | | | |
| Eurocastle Investment Limited | 550m | | N | | | |
| Eurocommercial Properties N.V. | 3,6bn | | N | | | |
| NSI N.V. | 1,2bn | 974k | N | | | |
| Unibail-Rodamco SE | 40bn | | Y | GRI G4 | 51,000 | BREEAM |
| Vastned Retail N.V. | 42m | | Y | GRI G4, EPRA | 1,300 | - |
| | | | | | | |
| Norway | | | | | | |
| Entra ASA | 2bn | 1,3m | Y | GRI G4 | 6,894 | BREEAM |
| Norwegian Property ASA | 750m | | Y | GHG Protocol | 4,115 | - |
| | | | | | | |
| Poland | | | | | | |
| Atlas Estates Limited | 82,6m | | N | | | |
| Globe Trade Centre S.A. | 1,6bn | 596k | N | | | |
| | | | | | | |
| Ireland | | | | | | |
| Green REIT Plc | 1,31bn | 2,5m | Y | GRESB, EPRA | - | BREEAM |
| Hibernia REIT Plc | 1,2bn | | N | | | |
| Irish Residential Properties REIT Plc | 470m | | N | | | |
| | | | | | | |
| Spain | | | | | | |
| Axiare Patrimonio Socimi S.A. | 860m | | N | | | |
| Hispania Activos Inmobiliarios, S.A. | 1,5bn | | Y | GRI G4 | 27,000 | 1 LEED |
| Inmobiliaria Colonial, S.A. | 6,9b | | Y | GRI G4, EPRA | 19,118 | 18 BREEAM, 5 LEED |
| Lar España Real Estate SOCIMI, S.A. | 1,275bn | | Y | GRI G4 | 3,572 | BREEAM |
| MERLIN Properties SOCIMI, S.A. | 10bn | 3,96m | Y | GRI G4 | 9,319 | 22 Certified assets |
| Realia Business, S.A. | 1,859bn | 400k | N | | | |
| Renta Corporación Real Estate, S.A. | 237m | | N | | | |

| | | | | | | |
|--|---------|--------|---|--------------------------|--------|----------------------|
| | | | | | | |
| Sweden | | | | | | |
| Atrium Ljungberg AB | 4,18bn | 1,179m | N | | | |
| Castellum AB | 7,41bn | 860k | Y | GRI G4 | 8,585 | BREEAM, LEED, MJB |
| Catena AB | 506m | 1,5m | Y | GRI G4 | 4,763 | - |
| Diös Fastigheter AB | 1,98b | | N | | | |
| Fabege AB | 2,3bn | | Y | GRI G4 | 1,200 | |
| Fastighets Balder AB | 9,23bn | | N | | | |
| Hemfosa Fastigheter AB | 3,92bn | 2,79m | N | | | |
| Hufvudstaden AB | 3,81bn | | Y | GRI G4 | 1,100 | |
| Klövern AB | 4,2bn | 2,84m | Y | GRI G4 | 10,492 | BREEAM, LEED, MJB |
| Kungsleden AB | 3,15bn | 2,3m | Y | GRI G4 | 17,513 | 2 LEED |
| Platzer Fastigheter Holding AB | 1,42bn | | N | | | |
| Wallenstam AB | 3,86bn | 1,1m | Y | GRI G4 | 623 | |
| Wihlborgs Fastigheter AB | 3,55bn | 1,858m | Y | GRI G4 | 6,120 | LEED, BREEAM |
| | | | | | | |
| Switzerland | | | | | | |
| Allreal Holding AG | 3,485bn | | N | | | |
| HIAG Immobilien Holding AG | 1,1bn | 489k | Y | - | - | Minergie |
| Mobimo Holding AG | 2,41bn | | Y | GRI G4, EPRA, CDP, GRESB | 14,390 | Minergie, DGNB |
| PSP Swiss Property AG | 6,03bn | | Y | EPRA | 15,000 | Minergie, LEED |
| Swiss Prime Site AG | 8,8bn | 1,45m | Y | GRI G4 | 35,000 | Minergie, LEED, DGNB |
| Züblin Immobilien Holding AG | 282m | | N | | | |
| | | | | | | |
| Turkey | | | | | | |
| Akfen Gayrimenkul Yatırım Ortaklığı A.Ş. | | | N | | | |
| Alarko GYO A.Ş. | 3m | | N | | | |
| Doguşş Gayrimenkul Yatırım Ortaklığı A.Ş. | 800m | | N | | | |
| Emlak Konut Gayrimenkul Yatırım Ortaklığı A.Ş. | | | N | | | |
| İş GYO A.Ş. | 4bn | | N | | | |
| Net Holding A.Ş. | 230m | | N | | | |

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| | | | | | | |
|--|---------|--|---|--|--|--|
| Sinpaş GYO A.Ş. | 560m | | N | | | |
| Torunlar Gayrimenkul Yatırım Ortaklığı A.Ş. | 2,597bn | | N | | | |

Appendix 2. Answers of the internet survey

| Age group | Job position (description) | Field of business of your company | Countries of operation | Which of the following environmental certification schemes are you using, if any? | How many construction projects is your company annually involved in? |
|-----------|---|--|---|---|---|
| 46-55 | Business and Product development | Construction | International | LEED;BREEAM;Svensk miljåbyggnad | 200+ |
| 36-45 | Team Leader / Project Manager | Architecture;Construction;Consultancy | Germany | Passivhaus House, KfW Efficient house | 8 projects |
| 36-45 | Project manager | Engineering;Consultancy | Sweden | LEED;BREEAM;Miljåbyggnad | 500 (approx) |
| 26-35 | Architect mid level | Architecture | Sweden | LEED;Miljåbyggnad | 10-15 |
| Over 55 | Founder | Architecture;Construction | USA, Scandinavia, Africa | | 30-100 |
| 46-55 | Architect, Project manager | Information about PassiveHouses | Sweden | | None |
| 46-55 | senior green business developer | Construction | Several including Finland, Sweden and USA | LEED;BREEAM;The Swan Nordic ecolabel, Miljåbyggnad, Passivhaus Green Building | 1000 (but some are roads, concrete manufacturing and so on, not suitable for certification) |
| 36-45 | project manager | Engineering;Consultancy;Property/facility management | Sweden | LEED;BREEAM;Miljåbyggnad, Green Building | I dont know but perhaps 100 |
| 26-35 | Environmental engineer | Consultancy | Norway | BREEAM | 300 |
| 26-35 | Junior Green Building Specialist | Architecture;Consultancy | Poland | LEED;BREEAM | 10 |
| 46-55 | Consultant (and CEO) | Engineering;Environmental | Sweden | LEED;BREEAM | 10 |
| 36-45 | editor | Consultancy;information | Sweden | LEED;BREEAM;Miljåbyggnad | Non directly - but we provide information to many |
| 46-55 | Consultant | Engineering;Environmental | Sweden | LEED;BREEAM;HQE | 10-15 |
| 26-35 | Project Manager in LCA | Construction;Product manufacturing;Consultancy | France | LEED;BREEAM;HQE | 20 |
| 36-45 | Project Architect | Architecture | UK | LEED;BREEAM | 24 |
| 36-45 | Technical expert on the project "Energy Efficiency in Public Buildings" | Consultancy | Serbia | LEED | 20 |
| 26-35 | Senior Projectmanager | National Scheme Operator for BREEAM | Netherlands | BREEAM | 300 |
| 46-55 | Principal | Architecture | USA, UK, Europe, Japan. | BREEAM | 3 |
| 26-35 | Sustainability Consultant | Engineering;Consultancy | Global | LEED;BREEAM | More than I can count |
| Over 55 | Head of Sustainability | Product manufacturing | Europe, Middle East and Africa | LEED;BREEAM;DGNB;HQE;Ska | Several thousand every year |
| 26-35 | Business developer | Product manufacturing | Worldwide | | More than 1000 |
| 36-45 | sustainability consultant | Consultancy;Property/facility management | | LEED;BREEAM;DGNB | 5-10 |
| 36-45 | Energy Manager | Engineering;Consultancy | Turkey | LEED | 10 |
| 26-35 | Engineer - Sustainability consultant | Engineering;Architecture;Construction;Product manufacturing;Consultancy | Italy | LEED;BREEAM | 10 |
| 36-45 | Sustainability Consultant | Architecture | Belgium | BREEAM | 70 |
| 26-35 | Environmental Engineer | Engineering;Consultancy | TURKEY | LEED | 6 |
| 46-55 | ICT Engineer & senior project manager | Engineering;Consultancy | France, French Guiana, Middle East | LEED | 20 - Case of Oger International former job consultant-admin, research and ngo level, not involved in construction projects directly |
| 46-55 | architect | Architecture;ngo | uk, turkey, russia | LEED | |
| 26-35 | BREEAM assessor/HVAC engineer | Engineering | Estonia | LEED;BREEAM | 1 |
| 36-45 | Project leader | Engineering | Spain | LEED;BREEAM | 200 |
| 26-35 | Architect | Engineering;Architecture;Construction;Consultancy | | BREEAM | 4 |
| 46-55 | Co-owner | Consultancy | Europe | LEED;Living Building Challenge | 10 |
| 26-35 | Green Building & Sustainability Consultant | Consultancy | Suomi | LEED;BREEAM | Our unit have approx. 10 new projects each year |
| 46-55 | LTA johtaja | Engineering;Architecture;Consultancy | Finland, Estonia, Russia | LEED;BREEAM | more than 200 |
| 26-35 | Project Manager | Engineering;Construction;Consultancy | Lebanon & Gulf Area | LEED;BREEAM;GSAS & Estidama Pearl | 15 |
| 26-35 | Environmental Engineer | Engineering | FRANCE | BREEAM;HQE | |
| 46-55 | Sustainability Manager | Property/facility management | All | LEED | 100+ |
| 36-45 | Lead Sustainability Consultant | Engineering;Architecture;Construction;Consultancy;Property/facility management | Finland, Sweden, Estonia, Russia, China | LEED;BREEAM | |
| 36-45 | Senior Project Consultant | Engineering;Consultancy | Global | LEED;BREEAM;Passiv Haus, Living Building, WELL | 100+ |
| 26-35 | consultant-civil engineer | Engineering;Architecture;Construction;Consultancy | greece | BREEAM | 500+ |
| Over 55 | Consultant Sustainable Environment | Consultancy | Netherlands, Belgium | LEED;BREEAM;GPR (Dutch), EPG and EPA (Dutch EPBM) | None. Investors don't care. about 250. |

| How many of these projects are typically certified? | Does your company perform Life-Cycle Assessment (LCA)? | Have you personally performed LCA? | If you haven't participated or performed LCA, please tell us why | If you have performed an LCA, how much time did you spend doing it? | If you have performed or been involved in LCA process, what problems have you faced? |
|---|--|--|---|---|---|
| | Yes | Yes I have participated in LCA | | | Finding data |
| 6 projects | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement; it is too difficult; it is too pricey | | |
| 75 | Yes | Yes I have participated in LCA | It is too difficult; Lack of know-how | 1-4 weeks | It takes too much working hours; Finding data |
| 5-6 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | | |
| Many | Yes | Yes I have participated in LCA | Working with a national LCA project | More than a month | Finding data |
| None | No | No I have not done LCAs neither participated | | | |
| 50 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | | |
| 10 | No | Yes I have led an LCA process | | More than a month | Finding data; Have done it by hand |
| 5 | Yes | Yes I have led an LCA process | | Less than a week | It takes too much working hours; Finding data |
| 0 | Yes | Yes I have led an LCA process | I just started and I'm involved in 2 projects | I'll tell you after I finalize this :) | Finding data |
| 10 | No | Yes I have participated in LCA | Have not needed or have not had a client requirement | | |
| 10-15 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | | |
| 15 | Yes | Yes I have participated in LCA | Have not needed or have not had a client requirement | 1-4 weeks | Finding data |
| 6 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | 1-4 weeks | |
| 300 | No | Yes I have participated in LCA | | | Finding data |
| | Yes | Yes I have participated in LCA | | Less than a week | Difficulties using the tools; Finding data; Understanding calculations |
| 1 | Yes | Yes I have participated in LCA | I am an assessor | As necessary. | Design and build a project then answer this for yourself. |
| Depends on location. In the UK, certification (BREEAM) is linked to the planning process, particularly in London, therefore the number is quite high. | Yes | Yes I have led an LCA process | | Less than a week | Finding data |
| Probably less than 5% | Yes | Yes I have led an LCA process | | | |
| 90% | Yes | Yes I have participated in LCA | | Year and years. It's horrible | Difficulties using the tools; it takes too much working hours; Finding data |
| 4 | Yes | Yes I have led an LCA process | | Less than a week | It takes too much working hours; Finding data |
| | Yes | Yes I have led an LCA process | | 1-4 weeks | Difficulties using the tools; Finding data |
| 10 | Yes | Yes I have participated in LCA | | | |
| 2 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | 1-4 weeks | Finding data |
| 3-4 | No | No I have not done LCAs neither participated | Lack of know-how | | |
| 5 | No | No I have not done LCAs neither participated | Not known | | |
| | No | No I have not done LCAs neither participated | Lack of know-how; not engaged in actual construction projects | | |
| 1 | No | No I have not done LCAs neither participated | It is too difficult; Lack of know-how; it is too pricey | | Finding data |
| 4 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | | |
| 0 | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | | |
| 10 | Yes | Yes I have participated in LCA | | More than a month | Finding data |
| Our units main service is to provide environmental certification scheme consultancy, so typically 90% of our units projects aim for and gets certified. | Yes | | | | |
| one or two | Yes | Yes I have participated in LCA | I have achieved the desired credits for certification in some other way; Lack of know-how | 1-4 weeks | It takes too much working hours; Finding data |
| 5 | No | No I have not done LCAs neither participated | | just follow up, some hours per case | Finding data |
| | Yes | Yes I have participated in LCA | | | |
| | No | Yes I have participated in LCA | | Less than a week | Finding data |
| | No | Yes I have participated in LCA | | Less than a week | Finding data |
| 10-15 | Yes | Yes I have participated in LCA | | 1-4 weeks | It takes too much working hours; Finding data |
| 25% | Yes | Yes I have led an LCA process | | 1-4 weeks | Finding data |
| None. Investors don't care. | No | No I have not done LCAs neither participated | Have not needed or have not had a client requirement | | |
| about 75% (new construction projects), 10% (renovation, refurbishment) | Yes | Yes I have led an LCA process | | 1-4 weeks | Difficulties using the tools; it takes too much working hours; Finding data; lack of certified materials, no unified LCA materials data |

| If performing LCA was easier, would you use it more? | | Do you think you will be using LCA within a year? | Do you use Building Information Modelling (BIM) in your projects? | Would you perform LCA if it would be integrated within BIM software? | Which of these 3 factors is most important to you concerning? | At what stage of your projects does your company typically perform an LCA? | |
|--|--------------|---|---|--|---|---|--|
| Yes | Yes | Yes | Yes | Yes | Reduced life-cycle cost/Improved building quality/Improved company image/Attracting investors | Early design phase | |
| Yes | I don't know | No | No | No | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality | Project planning phase/We do not perform LCA/LCA aspects are discussed but not calculated or certified | |
| Yes | I don't know | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Early design phase/Final design phase | |
| Yes | I don't know | Yes | Yes | Yes | Reduced life-cycle cost/Improved company image/fulfilling certification criteria | We do not perform LCA | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | Project planning phase/Early design phase | |
| Yes | Yes | No | No | No | Reduced environmental impact | We do not perform LCA | |
| I don't know | No | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Early design phase | |
| I don't know | Yes | No | No | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Project planning phase/Early design phase | |
| Yes | Yes | I don't know | No | No | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | Early design phase | |
| I don't know | I don't know | No | No | No | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | Project planning phase/Final design phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | We do not perform LCA | |
| I don't know | Yes | No | No | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | We do not perform LCA | |
| Yes | Yes | No | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | We do not perform LCA | |
| Yes | I don't know | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | We do not perform LCA | |
| Yes | Yes | No | No | No | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | we do not really do LCA ourself. We have a free LCA tool available on our website to encourage engineers/architects to use it | |
| No | Yes | Yes | Yes | Yes | Fulfilling certification criteria | Idiotic question - it depends on the client and contract. | |
| Yes | Yes | Yes | Yes | Yes | Reduced investment cost | It can be an iterative process, with initial calculation completed at scheme design, updated through developed design. | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/fulfilling certification criteria | Construction phase | |
| Yes | Yes | No | No | Yes | Reduced investment cost/Reduce life-cycle cost/Attracting investors | Project planning phase/Tendering phase/Early design phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Final design phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced investment cost/Improved company image/Attracting investors | Project planning phase/Tendering phase/Early design phase/Final design phase | |
| Yes | Yes | No | No | Yes | Improved company image/Attracting investors/fulfilling certification criteria | Final design phase | |
| Yes | Yes | No | No | Yes | Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | We do not perform LCA | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Improved building quality/Improved company image/Attracting investors | We do not perform LCA | |
| Yes | I don't know | No | Yes | Yes | Reduced environmental impact/Improved building quality/fulfilling certification criteria | Project planning phase | |
| Yes | I don't know | No | No | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/fulfilling certification criteria | We do not perform LCA | |
| Yes | I don't know | Yes | Yes | Yes | Image/Attracting investors/fulfilling certification criteria | We do not perform LCA | |
| Yes | I don't know | No | No | No | Reduced environmental impact/Attracting investors/fulfilling certification criteria | We do not perform LCA | |
| I don't know | Yes | Yes | Yes | Yes | Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image | Final design phase/Construction phase | |
| Yes | I don't know | Yes | Yes | Yes | Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image | Early design phase/Final design phase | |
| Yes | I don't know | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Early design phase/Final design phase/Construction phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced investment cost/Improved building quality/Improved company image/fulfilling certification criteria | We will be performing LCA at early design stage | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Improved company image/Attracting investors/fulfilling certification criteria | Early design phase/Final design phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality | Project planning phase | |
| Yes | Yes | No | No | No | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors | Project planning phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Tendering phase/Early design phase/Final design phase/Construction phase/Operative phase | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Improved building quality/Improved company image/fulfilling certification criteria | Project planning phase/Early design phase/Operative phase | |
| Yes | No | No | No | No | Reduced investment cost/Improved building quality/Improved company image/Attracting investors | We do not perform LCA | |
| Yes | Yes | Yes | Yes | Yes | Reduced environmental impact/Reduced investment cost/Reduce life-cycle cost/Improved building quality/Improved company image/Attracting investors/fulfilling certification criteria | Project planning phase/Tendering phase/Early design phase/Final design phase/Construction phase | |

| How helpful is CA for you in the following categories? (Achieving credits in certification) | How helpful is CA for you in the following categories? (Reducing overall environmental impact) | How helpful is CA for you in the following categories? (Reducing costs) | How helpful is CA for you in the following categories? (Alternative building design) | How helpful is CA for you in the following categories? (Improving the company image) |
|---|--|---|--|--|
| Helpful | Helpful | Somewhat helpful | Very helpful | Very helpful |
| Not helpful | Helpful | Helpful | Not helpful | Don't know |
| Helpful | | | | |
| Don't know | Somewhat helpful | Not helpful | Helpful | Not helpful |
| Don't know | | | | |
| Don't know | Helpful | Somewhat helpful | Very helpful | Helpful |
| Don't know | Don't know | Don't know | Don't know | Don't know |
| Don't know | | | | |
| Don't know | Don't know | Don't know | Not helpful | Not helpful |
| Very helpful | Somewhat helpful | Not helpful | Helpful | Somewhat helpful |
| Very helpful | Helpful | Not helpful | Helpful | Somewhat helpful |
| Very helpful | Very helpful | Somewhat helpful | Don't know | Don't know |
| Helpful | | | | |
| Don't know | Don't know | Don't know | Don't know | Don't know |
| Helpful | Helpful | Not helpful | Helpful | Don't know |
| Very helpful | Not helpful | Not helpful | Somewhat helpful | Helpful |
| Very helpful | Very helpful | Helpful | Helpful | Helpful |
| Don't know | Helpful | Helpful | Helpful | Don't know |
| | | | | |
| Very helpful | Helpful | Somewhat helpful | Helpful | Somewhat helpful |
| Somewhat helpful | | Not helpful | Somewhat helpful | Not helpful |
| | | | | |
| Helpful | Helpful | Somewhat helpful | Somewhat helpful | Somewhat helpful |
| Helpful | Somewhat helpful | | | |
| Don't know | Don't know | | | |
| | | | | |
| Helpful | Helpful | Somewhat helpful | Very helpful | Very helpful |
| Helpful | | | | |
| Don't know | Somewhat helpful | Somewhat helpful | Not helpful | Not helpful |
| | | | | |
| Helpful | Somewhat helpful | Helpful | Not helpful | Somewhat helpful |
| Somewhat helpful | Very helpful | Somewhat helpful | Somewhat helpful | Very helpful |
| Very helpful | Helpful | Not helpful | Not helpful | Helpful |
| Helpful | Helpful | Somewhat helpful | Helpful | Helpful |
| Don't know | Somewhat helpful | Helpful | Somewhat helpful | Somewhat helpful |
| | | | | |
| Helpful | Very helpful | Somewhat helpful | Very helpful | Helpful |
| Somewhat helpful | Helpful | Somewhat helpful | Not helpful | Helpful |
| Very helpful | Very helpful | Helpful | Helpful | Helpful |
| Somewhat helpful | Helpful | Helpful | Helpful | Very helpful |
| | | | | |
| Helpful | Somewhat helpful | Somewhat helpful | Not helpful | Somewhat helpful |
| Somewhat helpful | Somewhat helpful | Not helpful | Helpful | Helpful |
| Helpful | Don't know | Don't know | Don't know | Helpful |
| Helpful | Somewhat helpful | Not helpful | Helpful | Somewhat helpful |
| Not helpful | Helpful | Very helpful | Helpful | Somewhat helpful |
| | | | | |
| Very helpful | Helpful | Somewhat helpful | Very helpful | Helpful |
| Helpful | Helpful | Not helpful | Helpful | Helpful |
| Very helpful | Very helpful | Somewhat helpful | Not helpful | Somewhat helpful |
| | | | | |
| Very helpful | Helpful | Somewhat helpful | Helpful | Somewhat helpful |

| How helpful is LCA for you in the following categories? (Automatic answers) | Which of the 3D modelling softwares do you use? | What tool(s) / software(s) do you use for building LCA? | How satisfied are you with the LCA tool(s) / software(s) your company is currently using? Please explain briefly why. | Which factors do you consider important when choosing an LCA tool? |
|--|---|--|--|--|
| Helpful | ArchiCAD/AutoCAD/Revit | TEAM | 4 Compliance with EN | Price/Support/Quality of the databases/Precision of the results/Simplicity of use |
| Somewhat helpful | doing mainly consultations and engineering | | | |
| Not helpful | | none | | |
| Helpful | ArchiCAD/Revit/sketchup_3ds max | NetBalance | 3 Everyone seems to have their own version | Quality of the databases/Precision of the results |
| Don't know | ArchiCAD/AutoCAD | | | |
| Don't know | AutoCAD | I don't know | 3 I don't know but that was not an alternative above | Price/Quality of the databases/Precision of the results/Simplicity of use |
| Not helpful | | | 1 Not using one | Price/Support/Quality of the databases/Simplicity of use/How many credits can you achieve |
| Somewhat helpful | Revit | 360Optimi | 4 I'll tell you more after I'll complete one :) | Price/Support/Quality of the databases/Simplicity of use |
| Somewhat helpful | I do not model others in the project do | | | Price/Support/Quality of the databases/Precision of the results/Simplicity of use/How many credits can you achieve/Automated data transfer from BIM |
| Don't know | AutoCAD/Tekla | | | |
| Don't know | We do not use 3D programs other consultants in the project does | | | |
| Helpful | ArchiCAD/Revit | ELUDE | 3 Could be more automatic for the selection of relevant EPD | Price/Support/Quality of the databases/Precision of the results/Simplicity of use/How many credits can you achieve/Automated data transfer from BIM |
| Somewhat helpful | Revit | | | Price/Quality of the databases/Precision of the results/Simplicity of use |
| Don't know | AutoCAD/Revit | | | Automated data transfer from BIM |
| Not helpful | | | | |
| Not helpful | AutoCAD/SketchUp and Brazil | Our own free tool: https://www.dgbc-rlf.com/rlf.html | 1 Not enough data available. We should try to make a european database which is much more complete (to the new european standard) and use it for all european countries seems to have it's own databases (for no database) and download it (called data methods) | Quality of the databases/Simplicity of use |
| Not helpful | Revit | BREEM green book guide, etc., etc., | 3 It is obvious to me that you have not concept of what you are asking. | N/A |
| Not helpful | AutoCAD/Revit | We have an in-house tool. We also use Gabi, and the IES IMPACT tool. | 4 Our in-house tool is quite straight forward to use. | Support/Quality of the databases/Simplicity of use |
| Don't know | AutoCAD/Revit | Gabi | 2 Talks too long | Price/Support/Precision of the results/Simplicity of use |
| Not helpful | AutoCAD | LEGEP, 3ds tool, Athena tool | LEGEP is too complicated, but has a scientific depth. 3ds and Athena are easy to use but it feels like it stays only on the surface... | Price/How many credits can you achieve |
| Somewhat helpful | AutoCAD | onedick- Ninova | 4 easy to use. | Price/Support/Quality of the databases/Precision of the results/Simplicity of use/How many credits can you achieve/Automated data transfer from BIM |
| Somewhat helpful | Vetconworks | None | There is none. | Support/Quality of the databases/Precision of the results/Simplicity of use |
| Helpful | AutoCAD | Sima-Pro (we consider to use Simapro for our future projects) | | Price/Support/Quality of the databases/How many credits can you achieve |
| Helpful | AutoCAD/Revit | | 2 | Quality of the databases |
| Somewhat helpful | AutoCAD | | | |
| Helpful | AutoCAD/Revit | BRE GreenGuide | 3 standard database offers some opportunity to perform LCA with less detailed calculations. We are not using any software | Price/Support/Quality of the databases/Precision of the results/Simplicity of use |
| Somewhat helpful | AutoCAD/Revit | None | | Price/Support/Quality of the databases/Simplicity of use |
| Somewhat helpful | AutoCAD/Revit | Gabi, Simapro | 4 | Price/Quality of the databases/Precision of the results/Automated data transfer from BIM |
| Not helpful | ArchiCAD/AutoCAD/Revit/Tekla | Imuri and 360Optimi | 3 They work, but both have limitations | Quality of the databases/Automated data transfer from BIM/Transparency of calculation results transfer from BIM |
| Somewhat helpful | ArchiCAD/AutoCAD/Tekla | Company own templates and Microsoft standard software | 4 Self developed for certain purpose. | Price/Support/Quality of the databases/Precision of the results/Simplicity of use/Automated data transfer from BIM |
| Not helpful | Revit | 360 Optimi | We recently purchased the license for 360 Optimi and we have not tried it yet. | Price/Support/Quality of the databases/Simplicity of use/How many credits can you achieve |
| Not helpful | AutoCAD/Revit | COCON | 2 Some bugs in the data processing | Price/Quality of the databases/Open databases: possibility to define new products |
| Don't know | Don't know | | 3 | Quality of the databases/Precision of the results/Simplicity of use |
| Somewhat helpful | AutoCAD/Revit | Optimi 360 | The software is relatively straight forward to use and provides usable reports for LEED and BREEM certifications (so little or no additional work required to provide valid evidence to a certifying body). | Price/Quality of the databases/Precision of the results/How many credits can you achieve/Automated data transfer from BIM |
| Don't know | Revit | in-house software | 3 Requires a lot of info from the design team | Quality of the databases/Automated data transfer from BIM |
| Helpful | AutoCAD/Revit/Tekla | (Dutch) GreenCalc, BREEM Mat 1 calculator from DGB, BRE Mat 1 calculator | | Support/Quality of the databases/Precision of the results/Simplicity of use |
| Helpful | AutoCAD/Revit | | 3 insufficient environmental material data from manufacturers of building materials | Support/Quality of the databases/Precision of the results/How many credits can you achieve/Automated data transfer from BIM (interphational unambiguous acceptance if tool must be third party certified |

Appendix 3. Benchmark of GHG emissions from building LCA

| Buidling | Building type | Certificat e | m2 | kgCO2-eq | kgCO2-eq/m2 | kgCO2-eq/m2/a |
|----------|---------------|--------------|---------|----------------|--------------|---------------|
| 1 | Office | BREEAM | 27,690 | 72,571,114 | 2,621 | 44 |
| 2 | Office | BREEAM | 3,400 | 4,816,591 | 1,417 | 24 |
| 3 | Office | BREEAM | 8,500 | 7,026,008 | 827 | 14 |
| 4 | Office | BREEAM | 5,500 | 7,397,772 | 1,345 | 22 |
| 5 | Office | BREEAM | 27,050 | 11,771,016 | 435 | 7 |
| 6 | Office | BREEAM | 20,000 | 50,180,686 | 2,509 | 42 |
| 7 | Office | BREEAM | 115,600 | 443,047,433 | 3,833 | 64 |
| 8 | Office | BREEAM | 18,000 | 19,502,125 | 1,083 | 18 |
| 9 | Office | BREEAM | 26,500 | 110,990,522 | 4,187 | 70 |
| 10 | Office | BREEAM | 8,300 | 30,610,920 | 3,680 | 61 |
| 11 | Office | BREEAM | 15,000 | 11,404,405 | 760 | 13 |
| 12 | Office | BREEAM | 20,300 | 9,970,051 | 491 | 8 |
| 13 | Office | BREEAM | 10,780 | 36,154,013 | 3,353 | 56 |
| 14 | Office | BREEAM | 21,220 | 47,747,056 | 2,250 | 38 |
| 15 | Office | BREEAM | 6,000 | 7,617,649 | 1,270 | 21 |
| 16 | Office | BREEAM | 15,600 | 16,838,002 | 1,079 | 18 |
| | | | | Average | 2,158 | 36 |

| Buidling | Building type | Certificat e | m2 | kgCO2-eq | kgCO2-eq/m2 | kgCO2-eq/m2/a |
|----------|---------------|--------------|--------|----------------|--------------|---------------|
| 1 | Retail | BREEAM | 61,777 | 286,455,466 | 4,637 | 77 |
| 2 | Retail | BREEAM | 3,639 | 29,719,852 | 8,167 | 136 |
| 3 | Retail | BREEAM | 19,280 | 30,981,035 | 1,607 | 27 |
| 4 | Retail | BREEAM | 49,100 | 218,121,425 | 4,442 | 74 |
| 5 | Retail | BREEAM | 32,970 | 1,203,089 | 36 | 1 |
| 6 | Retail | BREEAM | 19,000 | 45,653,776 | 2,403 | 40 |
| 7 | Retail | BREEAM | 50,000 | 200,458,234 | 4,009 | 67 |
| 8 | Retail | BREEAM | 2,600 | 31,218,375 | 12,007 | 200 |
| 9 | Retail | BREEAM | 13,295 | 652,057,797 | 49,045 | 817 |
| 10 | Retail | BREEAM | 5,441 | 13,276,132 | 2,440 | 41 |
| | | | | Average | 3,958 | 66 |